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CONTENTS.

PAGE.

Perrine and Baum on Aluminium Wire.
Discussion at Philadelphia, May 18, 1900 79
Crehore and Squier on the Sine Wave in Cable Telegraphy.
Discussion at Philadelphia, May 18, 1900 86
Pupin on Wave Transmission over Cables and Long Lines.
Discussion at Philadelphia, May 18th, 1900 100
Important European Electrical and Engineering Developments at the Close of the 19th Century. (Illustrated.) By William J. Hammer. February 28th, 1901.
The Telephonograph 105
Langen Mono-Rail Suspended Railway 113
The Nernst Lamp 120
The Osmium Lamp 132
The Steam Engine and its Competitors 135
High Furnace Gas and Big Gas Engines 139
New Korting 2-Cycle Gas Engine 143
Oechelhauser Gas Engine 147
The Steam Turbine 149
The Sulphur Dioxide Gas or S O2 Engine 150
A Trolley Omnibus 157
The Electric Plough 158
Ganz & Co.'s High Tension Three-Phase R. R. System 160
Siemens & Halske High Tension Three-Phase R. R. 165
The Jungfrau Three-Phase Railway 173
Advertisements 181

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Discussion.

[See p. 391, June and July, 1900 Issue.

The President—Gentlemen, the paper is now open for discussion.

Mr. Steinmetz:—Mr. President, with your permission I desire to say a few words regarding this extremely interesting paper. I do not see any reason for using two letters when a single letter can be used. I would leave the Omega out and put in the Standard letter. But that is a minor matter.

Dr. Perrine:—It was done to show where the l came from which previously we had worked out.

Mr. Steinmetz:—This shows the capacity of the line; and something very important is the condition found in power transmission, but to a certain extent it is of secondary importance; that is to say, it is not so essential to calculate the extent of capacity accurately, but with approximation; and in most cases almost any approximation will do. What is necessary is rather to determine the limiting value of the effect of capacity, to see whether this effect is of sufficient amount to require a more accurate investigation; and as a rule we find it is not. Here in this very long transmission, while it is considerable, it is not of such importance as to require a very accurate determination of its effect. The only case of which I know where the capacity is of considerable magnitude is probably the transmission of my friend Mr. Nunn; and this is considered due to the very high voltage and the comparatively small amount of power; and my friend Mr. Nunn told me had obtained some valuable information.

There is one further remark I would like to make regarding the last experience referred to by the speaker, in these synchronous motors taking excessive current. Now it is quite possible that wave-shape had something to do with this, but I am not quite sure of that, for somehow or other, I do not really believe much in the wave-shape. While wave-shapes are very important theoretically, I have never yet found any case where any difficulty could be traced to the wave-shape without any doubt—without permitting any other explanation. On the other hand, there are many cases where disturbances have been observed, and explanations made for it by the wave shape, but after being investigated they were found not to have anything to do with it. In one case of a converter the current increased out of all proportion as the load came on, and I found somebody made a very ingenious explanation of how that was due to the wave-shape; but I sent one of my assistants there, who did not believe in wave-shape, and after carefully looking over it he found the series field reversed, and so the armature had to magnetize the field. Now, in coming to this particular instance here, it may be the wave-shape, but I think there is possibly a different explanation, though I cannot say which is accurate, the real

reason being that I am not sufficiently familiar with the conditions. If you take a transmission line equal in length to one-fourth of the wave—a one-fourth wave-length—and then impress a constant electromotive force at the generator end of the line, you will get at the receiving end a constant current. The transmission line has such capacity or induction as will be one-fourth of the wave. [Illustrating]. If the length is exactly this, whatever apparatus you put at the receiver end it will always take the same current. This is an extreme case, but even with a line very much shorter than that, as soon as the length of the line increases to a certain extent by the effect of the capacity and self-induction, there is such an effect at the receiving end as tends to regulate for constant current. A very frequent case, the shunting of an induction motor at the receiving end of the line, or a shunting of a self-induction coil, will throw the self-inductive capacity of the system sufficiently out of balance to spoil this tendency to constant current regulation. I do not know whether this is a condition existing here or what else the condition was. What I want to say is that from the data given here we are not entitled yet, I think, to conclude that the wave-shape had anything to do with the phenomenon, and I should rather believe that the wave-shape had nothing to do with it.

Dr. Perrine:—Before Mr. Steinmetz sits down—I confess I am very nearly as much a disbeliever in wave-shapes as Mr. Steinmetz is, but I have been faced by this problem. Starting with the generator unloaded, there was a motor current of 23 amperes. With a lagging current of 18 amperes at the receiver the motor current dropped to 11½ amperes; and Mr. Steinmetz cannot say that there is anything the matter with the motors, because they are his own motors.

Mr. Steinmetz:—The only suggestion I would make of that, is inserting self-induction.

Mr. Baum:—Mr. President, Mr. Steinmetz in his last remarks has given, in another way, our explanation; that is, instead of saying the excessive motor current was due to wave-shape, suppose we say it was due to "hunting" at 60 cycles per second. That means exactly the same thing. In our paper we say the motor during part of the cycle acted as a motor and during the remainder of the cycle as a generator. Does not that mean the same thing as saying that it was "hunting" (electrical hunting) at 60 cycles per second? In the motor we believed there was a triple frequency current, and on that assumption went to work to cure the trouble. The General Electric Co.'s engineer out there did not agree with us; like Mr. Steinmetz, he said it was "hunting." He wrote back to the main office and sent all our measurements; they sent back a report that it was "hunting," and sent out bridges to put in between the pole tips of the motor—the usual cure for "hunting." We predicted that the bridges would not cure the trouble. The fact is that the bridges had no

effect whatever to reduce the motor current. Then to show that our explanation was the correct one we threw in the induction coils and the motor current immediately dropped, in one case one-half, and in the other from 14 to 3 amperes, and could then draw leading or lagging current by varying the excitation. Before that we could do nothing at all with the excitation to reduce the current taken by the motors.

DR. KENNELLY:—Mr. President and gentlemen. We started with a paper on aluminium, and aluminium is so light that we got into the airy fields of mathematics; and with your permission I beg to say a few words now about aluminium and the wire, because the task fell to my lot to make measurements of samples of the wire, and I examined about a hundred samples and made as careful tests as I could upon its electrical and mechanical properties. The electrical properties were very nearly uniform. There was very little difference between the electrical conductivity of any of the lots that I had occasion to examine, and this appeared to be due to the relatively high degree of purity of the wire and the absence of admixture or alloy. The fracture of the wire always assumes a characteristic form and terminates in a peculiar nipple at each side of the break. I think that if the wire were defective it would be more likely to break off flush. With steel wire there is a small, steady, elastic elongation until you get beyond a certain limit, and then the permanent elongation increases very rapidly; but in the case of aluminium wire, you cannot assign any particular point at which the elastic limit can be said to lie. All you can say is that the stress shall not exceed a value at which the elongation shall be appreciable; and from the statements that have been made to us in the paper, it seems that there is no difficulty in arriving at that point in practice.

DR. PERRINE:—We derived that from your curve

DR. KENNELLY:—In regard to the determination of the pressure at the receiving end of a line, if the capacity of the circuit is assumed as collected together into one condenser and located in the centre of the line, the assumption is quite good enough for most practical cases, namely, a case of low frequency on a line not greater than 200 miles in length, and with ordinary capacity and inductance of overhead copper conductor, but you may have cases of short wires with exaggerated capacity or inductance, and in cases of high frequency you will be unable to obtain sufficient accuracy; and in such cases I believe in the use of hyperbolic functions. I don't think there is any difficulty in using them after a few trials.

I want to make one humble protest against the use of what I think is an inversion, or what I will submit is an inversion of the direction of reactances, geometrically. I see the reactances in this paper are all written $r - jx$, and, as a mere matter of convention, I would submit that that is undesirable. It is not a

question of what is right or wrong. If you accept the notation, it is all right. I have always maintained that the reactance of a reduction coil should be written $r+jx$. I have the honor to differ upon this point with Mr. Steinmetz, who, I think, is responsible—I am not sure, but I think he is responsible—for introducing negative reactance, and I think he justifies his position upon astronomical grounds. I am quite ready to sacrifice my view if it should be generally agreed that reactance should be measured negatively and a condenser measured positively, and with a lagging current which should be measured in that direction. But, in trigonometry, we always measure angles positively in the counter clockwise direction, and a negative lag angle should be in the negative direction. I think it would be a good plan to bring that matter up and have a consensus of opinion. Whenever I read Mr. Steinmetz's mathematics, I have to stand on my head in order to understand the reactances.

Mr. Steinmetz:—Having been challenged regarding these formulæ, I may give my reason for having adopted them. It is not based on astronomical reasoning. Astronomical reasons led me to adopt the counter-clockwise direction. The reason it happened to be minus in my case and plus in another, in the method of graphic representation, it is nothing but a symbolic method of graphical representation. Long before anybody thought of electrical engineering, polar co-ordinates were used, with the time as angle or amplitude, and the instantaneous value as vector. Now, somehow or other, when graphical representations were first introduced—they were introduced by Kapp, I think, and others—they seem not to have thought of the familiar system of polar ordinates, but discovered and invented a different method of representation. They chose a line representing the maximum value of the current, and they let that line rotate around, and a projection of this line represented the instantaneous value. It is a very interesting method, and it has been introduced to a certain extent; the only objection is, that a better representation has been known in the common polar co-ordinates since a few centuries. Here is the sketch of Dr. Kennelly. In his representation, this current is lagging behind the electromotive force, because if he takes his line and revolves it around it comes there later. But if you represent it, not by some artificial method but by the standard polar co-ordinate system, then we denote the electromotive force by the diameter of its polar circle. If the current is lagging, the maximum value of the current will be reached at a later time. So these signs depend upon the graphical method you choose in starting. You may use a polar system, which is used in all engineering branches, as, for instance, in giving the valve motion of steam engines, or you may choose some special method not used anywhere else.

The President:—Is there any further discussion? Mr. Nunn, I believe, has had considerable experience with aluminium lines, and we shall be very glad to hear from him.

MR. PAUL N. NUNN.—The question of aluminium lines is one of a great deal of interest, I believe, to all who have long distances to reach, especially where the distances are such and the conditions such as to permit of the use of quite high pressure. I do not believe that I have anything to offer the INSTITUTE this morning upon the question under discussion. The questions involved are pretty complicated. I am not prepared to offer a word on the authentic evidence given this morning. I have found a great deal of difficulty in satisfying myself of just the conditions which would obtain upon the erection of long aluminnium lines, and while I suppose the information at hand, with most of us, is sufficient to determine pretty closely, within 1.5 per cent., I think that is near enough. We are interested in those practical results, but closer than that I think it is a question of scientific interest very largely, and a great many of us are not prepared to go into such a question to the extent necessary, simply on the ground of scientific interest. Our observations of the use of aluminium are very interesting, but I do not know that there is anything in it to throw a particle of light on the question as discussed here this morning. I may say that I think we are in a position to second the statement which has been made that the alloyed aluminium, or certain alloyed aluminium, is not safe. I do not think this should perhaps be expressed too generally. There is a line in very successful operation, I understand, and I cannot learn that there has been a particle of trouble from it, in which the alloy is very considerable, put in very carefully; but the common alloyed aluminium, which I believe instead of being alloy is impure aluminium, handled under the brand of XX and BB or something like that, is defective because it is not homogeneous. The INSTITUTE might be interested in knowing that in about six miles of a certain aluminium circuit which we erected something over a year ago, during the first month of its erection, I cannot say use, it broke, an average of every 100 feet in length, or every span. There were fifty-two breaks to a mile in a month. It took the services I believe of four men all the time to repair breaks. We simply let that go on, to see how long it would continue. We do not know; we finally stopped it. There were but four breaks in that six miles which showed an elongation of 2%—enough elongation so that the eye could distinguish it; and in several cases I noticed something which appeared like a physical defect, a sliver, along the side, which showed something in the way of drawing; it was rough; the appearance was somewhat crystalline, and apparently it had broken exactly as a piece of glass would break, that is, square. We photographed some of these ends and sent them to the Pittsburgh Reduction Company, and I think the trouble was understood the moment they saw the photographs. There was only one condition under which that could occur—the case of an ingot in which the impurity or alloy was not thoroughly mixed and did not produce a

homogeneous mass. It seems to me as if in the process of drawing, that impurity settles in the form of an infinitely thin stratum through the wire and that under conditions of moderate stress, probably in our case seldom exceeding 1,500 pounds to the square inch, it is attended with vibratory results. We have replaced much of this line, practically all, with pure aluminium, stranded, and have not had a particle of trouble. I think the question of resistance in joints is one with which we must labor for some time to come. I have learned that aluminium deteriorates particularly in a country where it is subject to alkalies, or to what is termed corrosive salt. The series of joints, which were at first very promising, afterwards became quite troublesome.

DR. PERRINE:—I would like to reply to one or two of these points that have been made. In regard to the elastic limit that Dr. Kennelly describes; from the curve which he gave here to-day we determined the strain that it would be safe to allow, and it was found to be satisfactory. I examined a large number of the breaks from the lines that were giving the most trouble, and found that in every case they were exactly as Mr. Nunn described them. The break is a shear, a sharp break, with a reduction of area on one side simply, which is the characteristic break of imperfectly alloyed wire. I have had a good deal of experience with imperfectly alloyed wire while trying to make silicon bronze, and the breaks were of that character; and almost all imperfectly mixed alloys will give that sharp break without any reduction in area. There is apparently a break from the wire falling, and getting a slight reduction of area on the under side and then shearing square across; it is not a break that is characteristic of aluminium any more than it is of any other imperfectly alloyed material. I take that characteristic of the break as one reason for saying these are imperfect alloys; and the other reason mentioned in the paper is that one of the lines which we had an opportunity to test gave trouble on one-half of the line and the other half gave no trouble at all. There were three breaks in one-half of the line due to short-circuit, or something falling across the line; and in the other half of the line there were 30 breaks a month, and that over its entire length, although it was said to be the same sort of wire The resistance of the whole line showed the wire to have only 90 per cent. electrical conductivity. This could not be due to hard drawing. By hard drawing you might get one or two per cent. resistance increase, but 10 per cent. increase must necessarily mean an alloy. The peculiarity of the elastic limit is not different from the peculiarity of the elastic limit of metals in the same group as aluminium, and in that respect copper groups with aluminium. In hard-drawn copper we have such a small percentage of elongation before breaking, but I have never yet seen any one who was able to draw the curve for the elongation of copper; but when we break soft-drawn copper we find it proceeds almost exactly as the aluminium was found to elongate in this case. It

is a general idea with many metallurgists that hard drawing does not change the relative position of the elastic limit. As regards these points there seems to be nothing new that aluminium has introduced into the art of metal working. It is simply that, being a metal that is liable to irregularities, it must not be used unless it is carefully inspected. I attribute our success in this line more to the careful inspection which Dr. Kennelly gave to the metal before we put it up than any other thing.

As regards the question of the signs of the complex quantities I thoroughly agree with Mr. Steinmetz. I studied complex quantities long before I studied alternating or direct currents. After I had studied complex quantities I began to study rectangular coordinates. The angle of lag seemed to me to be always the other way. It seems to me the system which Mr. Steinmetz developed is a rational system, and the only unfortunate thing is the man who has reached one system does not dare to touch a paper written by the man who has written in the other system.

THE SECRETARY:—There will be a collation served in this building at about one o'clock, and after that the remaining papers will be taken up. Professor Rowland will be very happy to have the members, after the collation or at any time, look about this building. It is very interesting. He has circulars describing the various courses given at the Institute, which may be had at the Secretary's office in the lobby.

MR. DUNN:—Mr. President, our Secretary's announcement of the collation reminds us of the very many courtesies that have been extended to us by the Reception Committee and by our brethren in Philadelphia, and if hospitality is one of the cardinal virtues it is certainly proper to acknowledge it. I am not sure but that in the motive of my remarks there is something in the nature of the expression by an old cynic, that gratitude is a desire for future favors. But be that as it may, I am sure that our experience here in Philadelphia has been so pleasant that we all desire such future favors and hope it will be soon when we shall again come here. I would therefore move that a committee be appointed by the Chair to draw up suitable resolutions acknowledging these courtesies and hospitalities which have been extended to us, and expressing in corporate action the same acknowledgment and thanks which have already been made by us individually. I am sure in speaking in this way I am voicing the sentiment of every member of the INSTITUTE who has attended this general meeting.

The resolution was carried and the President appointed as such committee, Calvin W. Rice, George F. Sever, and W. W. Ker.

THE PRESIDENT:—The next paper is entitled: "A Practical Transmitter using the Sine Wave for Cable Telegraphy; and Measurements with Alternating Currents upon an Atlantic Cable," by Dr. A. C. Crehore and Capt. G. O. Squier.

[See p. 348, May, 1900, Issue.]

Discussion.

Dr. Crehore:—Mr. President, please allow me one word in explanation of the point that Captain Squier makes. The fact that we have some letters that require successive signals in the same direction makes it easy to read if they occur in a certain order. Expert readers can easily pick out an *h* if it is isolated; but if you had a succession of *h's* or a succession of small *h's*, which is three dots, there is only earth in between; or if, for instance, three *c's* come out at the other end by a large alternating current, it makes a large record. If you had *s s* you would not get the separation between them that you would between *s o*, which is very easy to read. The point is that you have these bad letters, which are liable to occur in a succession and which you cannot easily read.

Dr. M. I. Pupin:—I am very glad that Captain Squier and Dr. Crehore have brought up this subject, before the Institute. It is an interesting subject, and has been worked out by them very carefully indeed. We have all heard that a long submarine cable on account of its capacity, is a very slow thing, and whenever we mention an Atlantic cable we also associate with it a certain amount of slowness. As a matter of fact I should think an Atlantic cable rather fast, because anything which is capable of *dissipating* as much as the Atlantic cable cannot be called very slow. Owing to the rapid increase of the attenuation constant with the frequency we have the infallible result that no matter how complex the current is which is sent in at one end, you are going to get at the other end its fundamental only. In other words, the amount of integral current that you send at one end of a cable will be in no definite relation to the amount of integral current that you receive at the other end. There will be a definite relation between these two amounts, if you consider the fundamental of the wave sent in. In other words, again, the wave energy which accompanies the fundamental is the available energy. That is the energy which goes through. The wave energy accompanying the upper harmonics is not the available energy. The wave energy accompanying the integral current sent into a cable behaves something like heat; and you might say there is such a thing as an entropy connected with it. Now what these gentlemen propose to do—and the proposition is an excellent one—is to get electrical energy sent, in which there is as large an amount of available wave energy as possible. There are two distinct advantages in that. In the first place, with a given impressed electromotive force at one end you can put a great deal more of available energy into the cable, and also with a great deal less of integral current than you would with a complex harmonic electromotive force. What does this bring about? The current sent in is smaller than when you use

a complex harmonic, and that seems to be a clean cut advantage. I do not think there is any doubt in anybody's mind, who has listened to the paper, as to the strength of their argument and as to the strength of their position.

The second excellent element in connection with this paper is that we have here, as far as I know, the first scientific measurement of the alternating current elements which come into consideration when an alternating electromotive force is applied to a cable. I have often thought myself, how large a current it would be necessary to put in at the sending end in order to get enough at the receiving end of a certain line, to work the siphon recorder—a siphon recorder as sensitive as the ordinary one. To be sure, we can sit down and make that calculation if we know the impedance of the cable for a given frequency, but it is always more encouraging to have actual experimental measurements, which Capt. Squier and Dr. Crehore have made. So that taking these two considerations into account, the one not only purely scientific but also a practical consideration, and the other a purely scientific consideration, I think that on the whole we can congratulate ourselves that these gentlemen have taken the trouble to prepare this careful paper and to have it embodied in our TRANSACTIONS.

MR. P. B. DELANY:—I want to make a few remarks in regard to the paper which has been read, and if any thing that I may say does not show reasonable familiarity with the merits of the paper I do not think it should be charged entirely to me, for unfortunately, I have not had a chance to study, or even read it, owing to the fact that there was some failure in the distribution, or delay in its preparation on the part of the gentlemen themselves, so that it was not available. I would like to make a few observations from a practical standpoint, and based upon what Dr. Crehore and Captain Squier have explained in reviewing the paper. It would appear that the efficiency of the ordinary transmitter as drawn by Dr. Crehore on the board, was taken as standard, regardless of its mechanical construction. I have found by experiments, that the speed in transmitting signals depends very largely upon the duration of the contact—I am now speaking of ordinary cables—between the battery and the cable itself, or through the condenser; and that while at the apex of the cable the electromotive force rises, we will say, to its highest point, I do not think this makes much difference, as every wave is sinusoidal at the receiving end of the cable. In an experiment made a few years ago between Ireland and, I will say, this side, a trial was made of two transmitters, one being the ordinary Wheatstone modification shown by Dr. Crehore. Without any change from the usual adjustment, the speed for regular signals was ascertained to be 188 letters per minute. The cable was then transferred to the other transmitter, having different kind of contacts for applying impulses to the cable. The speed at

the starting point was 207 letters per minute. That rate was taken at a guess and counted afterwards for verification. The arrangement for the trial was that the operator at the receiving end should make such observations regarding the character of the work as his judgment should dictate. At the first trial after the change of transmitters, at a speed of 207 letters, his remarks were, "Those signals are o. K, but too large. I will shunt my receiver and draw out the magnets"—it was an adjustable field—with a view of course of reducing the amplitude of the signals. He was told not to do that, but leave his magnets as they were, and to increase the tension of the adjustment of the suspended coil, to which is attached the siphon, and take advantage of the increased power as indicated by the greater amplitude of the signals for quicker return of the coil to the neutral point. His reply after receiving these instructions was, "All right. I will do as you say." The speed was then increased to 222 letters a minute, and his reply was, "Those are o. K."

Then he was asked if they were good enough for traffic. He said, "Yes, they are good enough for traffic"—which is always a crucial test in regard to cable signals. Then the cable was put back to the original transmitter, making shorter contacts, and he said "Those are all there, but infinitesimal. Will you increase the battery or shall I slacken the adjustment?" He was told, as these gentlemen have pointed out, that they could not increase battery power, but he must do everything that he could to break down the discrepancy between the two transmitters, and after some adjustment he got back to the original speed, 188 letters a minute, and said that they were "fair for traffic." There was a vast difference in the construction of the two transmitters in the point of duration of the contact between the battery and the line, one being the Wheatstone—the ordinary modification of the Wheatstone transmitter, where the rods are worked by a walking-beam, making the contact on passing through the holes, and the other being a scraping contact, with brushes above the paper and brushes below, the duration of contact being altogether dependent upon the size of the holes in the tape, whereas in the other case of course it would make no difference about the size of the hole, so long as it was sufficient to admit the point. It has been observed here, and it has long been well known, that with an alternating wave, not irregular, but with uninterrupted succession, you can get a greater number of waves in given time than in any other way. I find on land lines, with chemical recording, that the regular make and break alternations, without any attempt at breaking the circuit at the zero point—will give a record at a speed three times greater, and with perfect distinctness, than where the impulses are sent successively from the same current. As Captain Squier has observed, the definition cuts very little figure in the reading of cable signals. Unless the speed is very slow, or the cable very short, or the capacity very low the

definition will not be such as to form a basis to guide the operator. In the cross letters of course, even with ordinary reversals, there is a margin of speed very much greater than would be admitted by the inherent difficulties in the formation of letters where successive signals are sent. Therefore the advantages of a sine wave for the cross letters are not necessary, because the ordinary reversal gives definition to a degree far in excess of the speed admitted by the other letters. The mere fact, of finding it necessary to put the cable to earth after each letter, shows I think, that the claim made some time ago that breaking the circuit at the zero point eliminated difficulties arising from retardation caused by electro-static capacity, has not been realized in practice. If it is found advantageous to discharge the cable between the letters, I think it is quite evident that a definition, such as might be expected, is not gained in long cables by the mere fact of the voltage declining to a zero point, at which it is broken. The paper has great interest and has done a great service, I think, in arriving at some scientific data with regard to the signaling capacity of a cable. I for one appreciate very much what these gentlemen have done, and if their theoretical premises are correct with regard to the gain in the speed of cables over other methods, although nothing appears in the paper to show the difference in actual transmission, I for one shall be very glad to recognize it.

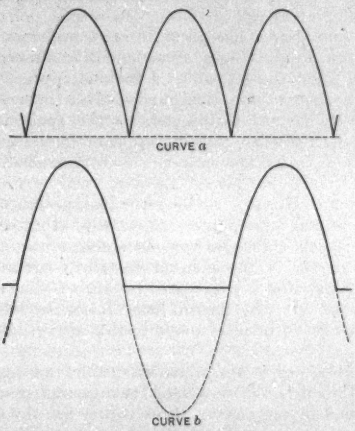
DR. FREDERICK BEDELL:—We have had presented a paper on a subject of much importance, which should be carefully considered and discussed from various standpoints. In using an alternating current in the manner described certain advantages have been gained, and it is proper to inquire what are the limitations and what are the possibilities in cable telegraphy, and whether advances are to be made in this direction, or in a different one.

The advantages of a sinusoidal wave for the transmission of current, whether it be for power or for other purposes, have long been recognized by engineers. So weighty are the arguments in favor of such a wave that the matter might be considered almost beyond controversy. Accepting then an undulatory or sinusoidal wave as being desirable for telegraphic as well as for power transmission, let us consider the features involved in its use.

In substituting a more or less sinusoidal alternating wave-form for impulses of the crude rectangular type, the corners of the impulses are rounded off and reactive disturbances avoided to a corresponding extent. This feature of the avoidance of sharp corners is a matter of very great importance in any system of telegraphy, be it alternating or direct. It is to be borne in mind, however, that the maximum reaction in an alternating current occurs at the zero point, and it is at just this point that the authors of this paper operate. With a rectified alternating current this effect is even greater, as will be obvious from an in-

spection of curve *a*. The sharp corners have been rounded off at the crest of the wave, but have been intensified so as to form a sharp point at the trough, the resultant wave being now far from sinusoidal. The code suppression of a semi-cycle still leaves a corner, as in curve *b*. But even with these defects the use of an alternating current is, as the authors show, an improvement on the usual practice, on account of the rounded corners at the crest.

Let us consider the effect of this sharp reactive point. In the apparatus which has just been described to us, two alternating electromotive forces are generated, of opposite polarity, and with coincident zero and maximum points; that is, electromotive force A is negative when electromotive force B is positive; then B is negative, while A is positive, etc. In the tape trans-



mission, the cable is connected either to A or to B according to a code.

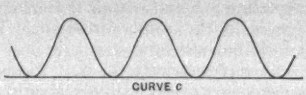
The condition of the cable so far as stress is concerned may, perhaps, be more readily understood by considering two synchronous swings, one to represent electromotive force A and one to represent electromotive force B. These swings pass each other at the zero position when at a maximum velocity. Now imagine a passenger transferring himself from one swing to the other as they pass. It is true that the two swings are at the zero point at the time of transfer, this being the position which they would both have if at rest, but they are moving in opposite directions and at the maximum velocity. With the alternating current transmitter that has been shown to us, has not the cable the some-

what uncomfortable task of the passenger in his transfer between the swings? We know that the passenger would be subject to physical stress as well as to mental strain. Is not the cable subjected to a similar stress? Would not its life be lengthened if this reaction could be avoided?

I have had occasion to do some work in the transmission of direct current impulses and am led to believe that a wave-form, as that shown in curve *c*, possesses many advantages. This is a direct current, of sinusoidal wave-form, without reactive points. The electromotive force rises gradually from zero and descends gradually, so as to be more or less tangent to the zero line. I have found that such direct current impulses may be satisfactorily produced by a continuously operated graduated rheostat interposed between the battery and the line.

By this means the line may be given a periodically increasing and decreasing potential, as the sine-wave in curve *c*. By properly grading the resistances, any desired wave form may be obtained to suit the conditions of service.

The apparatus may be readily constructed so as to give a double series of direct current impulses, one positive and one negative.



CURVE c

Now when the cable is connected sometimes to electromotive force A and sometimes to B, according to a code, the change is made at the time of minimum reaction, and reactive disturbance is practically eliminated.

If we consider two swings to swing so that they just meet but do not pass each other, our passenger could transfer from one swing to the other without inconvenience. Any possible code selection of impulses from A or B can not introduce a sharp point in the resultant curve, the transition being always gradual, a feature conducive to higher speed, higher permissible voltage, and (what must not be overlooked) a lessened liability to interruption and greater life of the cable.

There is one point of consideration in the matter of electrostatic hysteresis which is of physical interest. Its effect is such —either to a greater or less degree—that electromotive force and current cannot both be exactly harmonic. This is well recognized with ferric hysteresis, and the same is true when we have a capacity with an electro-static hysteresis loop.[1] The effect of such hysteresis is that to obtain a true sinusoidal current, the electromotive force must be adjusted so as to deviate to a certain extent from a sine-wave.

1. Such a loop obtained by the speaker with others is given in the TRANSACTIONS, page 525, vol. X.

In regard to the matter of equivalent voltage of a sinusoidal wave and any other, I would be inclined to take a position even more favorable to the sine wave than have the authors of this paper, who say that a sine wave with virtual voltage of 35 is equivalent to a battery voltage of 50, applied either directly or through a condenser. On account of the easy application and withdrawal of an undulatory electromotive force, I am inclined to believe we are nearer the truth if we take its virtual value as its true measure, and say that a sine or undulatory wave, either direct or alternating, with a virtual value of 50, as measured in any usual way, is equivalent to a battery voltage of 50 applied with full initial value without gradation.

In closing I beg to express my very high appreciation of the paper to which we have listened and to repeat my advocacy of a sinusoidal or undulatory wave and to call attention to the reactive disturbances which have been mentioned.

DR. CREHORE:—Mr. President, I want to take this opportunity of speaking on a special point raised by Dr. Bedell, and give the views as they appear to me, illustrating them by the diagram. It must be borne in mind that there are few kinds of letters in cable signaling; what we call the cross letters and letters that have signals in the same direction. It is almost impossible, at least I do not see how it is practical at the present time, to employ sine waves strictly for both kinds of letters. If you are going to use sine waves at all you should take the choice which kind of letters you will have the true sine waves operate, and I think it is most important to have the cross letters with the sine wave. Dr. Bedell's method uses the sine wave for the letters which are not cross letters, but does not use the sine wave for the cross letters. Allow me to redraw the curve. This (making diagram) being the zero axle, the letter A could consist of *this*, followed by *that*. The simple reversals would be, coming down here to the tangent. Now in no sense can we consider that a sine wave for sending impulses through the cable. The effect of such a wave as that would be equivalent in operating the receiver at the other end, through a motor sine wave. In other words, I anticipate that if such a wave as either of those two were tried you would get just the same result at the other end of the cable. You have to use a higher voltage in connection with Dr. Bedell's proposal than you do with a true sine wave. The sine wave which is proposed is double the frequency of the sine wave which we use. If you are working at a period of 5, which is a normal working period, therefore the other wave must have a frequency of ten. Though you send that sine wave directly into the cable, without having a direct current, or even if it is a direct current, at the other end you cannot see anything but a slight tremor, if you see that. In other words, having the recorder in the series, and sending in like *that*, you get practically the same thing. It will start up

there and go down to the zero line, because the condenser at the other end stops all current and you only get the pulsations after a while. Therefore it is unimportant what shape of curve these successive portions have for a given letter. For this reason if you send the first one alone and then allow the cable to be insulated until you care to send a reversal in, or the earth, the record is good at the other end. When you apply a battery to our brushes that is what happens. To illustrate by a particular case take the letter B. We have holes in the paper like *that*,—a dash and three dots. The brushes *here* make continuous contact there from beginning to end. If you apply a battery on these impulses you will find you get a negative impulse and then a positive impulse, which stops the current, and it remains stopped until you come to the end. We find that method gives good signals. They look better than they do to put anything in separately for these successive ones after the first. And I am very desirous of making a perforator which will send *these* signals. These holes represent A. (Illustrating). You will get a better record at the other end by doing that than you will by retaining these other impulses. C is a dash, dot, dash, dot. If a perforator is going to strike the hole in the upper line for a dot and a hole in the lower line for a dash and then one on the lower line for a space, it is difficult to do it with these feed-holes alone, since you have a punch which requires the operator to learn a different method. Of course a letter perforator, which is the coming kind of perforator to use, will easily overcome that difficulty and I hope we can experiment with such a plan as that. The point then of objection to this is that it has double the frequency of the sine wave and does not apply the sine wave to the most important case that exists; and it requires a higher voltage.

PROF. FRANKLIN:—Mr. President, when I listened to Dr. Bedell's suggestion it struck me at first as a very reasonable one. I have since thought, however, of one or two of the points mentioned by Dr. Crehore, and it occurs to me that there is one other thing in Dr. Bedell's suggestion which is not altogether rational, and that is that he loses sight of the fact that the circuit is only broken when the current is zero That is, the velocity of zero is an analogy of the two breaks. It would not apply in that case because the scheme only anticipates breaking the current when the circuit is at zero and has an adjustment in the machine for actually reaching that condition.

MR. C. P. STEINMETZ:—Mr. President, I have listened to the paper with very great interest, and consider it as one of the most important contributions, illustrating the investigation undertaken by the writers of the paper and continued now for several years. Considering that telegraphy is one of the oldest things in electrical engineering, and has made enormous strides in the last part of the century, it is remarkable that almost no attention has been given to the generating part of the power used in telegraphing.

Since an early day the same power has been used for make and break, and no attention has been given to a scientific investigation of the problem of generating power for telegraphy. The first investigation that I know of are these investigations of Dr. Crehore and Capt. Squier, and I think the results derived from them are of extreme importance. When the first paper was brought out by these gentlemen it struck me as showing the importance of using the sine wave. The same thought struck me which was referred to by Dr. Bedell to-day. In reality they do not use a sine wave, as I understand, but half a wave followed by a space. They do not use a complete wave. Now half a wave is not a sine wave. If you use the two half waves here—(illustrating by diagram on the board) it should be first said in the investigation that in a cable it is separated from the condenser. The change of electromotive force is the only thing that is important. What you really get by an adjacent wave of the same direction is the alternating current of greater frequency; and the positive part of the wave being rounded and the negative part being sharp, such a wave should be expected to work in a cable like this. The effect of using the half sine wave is a change to the double frequency, and a reduction of the effective value of the electromotive force. Now we have this cable acted upon by two frequencies and two electromotive forces. In frequency the upper signals follow each other with full electromotive force and the sub-frequency descends, which acts like such a wave—(illustrating) that is a wave of double frequency and effective value less than half the other one. Looking at this it should be expected that the most important of those high frequency waves was a higher electromotive force than the sine wave, because this wave can take care of itself and will smooth out, and that is still higher than the effective value of this distorted wave. That should be expected. I believe this wave proposed by Dr. Bedell would be preferable. This wave can be produced very easily by a machine. For instance, take a machine with a collector ring to one point of the armature, and then with a controller ring to one part of the commutator brushes and you get it this way. (Illustrating) It seems from Dr. Crehore's statement that experience does not agree with his theoretical reasoning, and the reason is something which I have not foreseen, and which I do not think could be foreseen by anybody who has not especially studied the thing radically; and that is that you really do not use these successive half waves as an electromotive force. You have successive half waves in the same direction, but there is not a sine wave, but a steady electromotive force; and in this case where you want a steady electromotive force the wave shape is immaterial. All you want is the maximum quantity of electromotive force, and the larger quantity you get by the sine wave rather than by this pulsating sine wave. That probably is the reason why the sine wave is preferable for the lower frequency only and the wave

shape in general is immaterial, because what we get then is a constant electromotive force.

MR. HAMMER:—Mr. President, I would like to ask Mr. Delany, Dr. Crehore, and Capt. Squier, one practical question, which it would be desirable to get on the record, if these gentlemen have no objections, and that is the maximum speed that they obtained under commercial conditions. It may be desirable to explain the circumstances under which that maximum speed is attained.

CAPT. SQUIER:—Mr. President and gentlemen, I can say that practically the same apparatus has been in actual traffic use on an Atlantic cable for several days at a time, during its development, in the last two years, and we are largely indebted to that actual practice. There are many things undoubtedly still to be determined which can only be determined by the test of actual traffic. When we come to speed, it is a difficult matter to state any way. They use one speed for traffic, where they require code words, which is a large per centage of the traffic now, such as the stock market, and have to use a slower speed. All I can say is we make a material gain in speed all along the line, for an equivalent voltage; but to state the exact amount would be impossible, because it depends on the particular cable, and the staff at the ends. A great deal depends on the people using the cable. Some men can read almost anything; they can almost read straight lines, they are so expert. So the whole matter is rather a difficult one to state, and if we state a gain in per cent. we have to explain how and under what conditions. So I only say in general it has proved more effective than any other wave we have employed. We have three books of sample signals here, which are open to any of you, and you can make a comparison for yourselves.

DR. KENNELLY:—Mr. President and gentlemen, we have had a theory of alternating current transmission as applied to submarine cables ever since Lord Kelvin's classical work upon that subject, prior to 1865; but I venture to say that we have had no practice, or practical knowledge, with a check upon the reliability of that theory, in published form until today. The importance of this paper it is difficult to overestimate, on account of the great value it may have from a practical standpoint, and on account of the still greater value it must inevitably have upon the engineering advance in this direction. During the last fifteen years very little progress has been made in the direction of increasing the speed upon long submarine cables. On short cables no one cares about the matter. You can put down any piece of wire in a cable, and insulate it well, and so long as it is time-constant, that is to say, so long as the product of its ohms and farads does not exceed one second—you multiply the number of farads by the number of ohms and get the product in seconds, and so long as you do not exceed one second, if you have a short cable, you can work it any way you choose, but

when you take a long cable, the time-constant goes up as the square of the length, the core remaining the same. When you come to five and six seconds, such as the Atlantic cables have, you have to apply the most refined means known to engineers in order to obtain commercial rates for the cable, and an advance of ten per cent. in the rate of signals is a material gain; material financially, because it means that you can employ a smaller core, less gutta percha, and less copper; material from a traffic point of view, because with a given cable once laid, you can send more words through it per minute. All this has been known and reduced to practice for ordinary rectangular wave, battery transmitters; but we have not till to-day had available measurements for alternating current transmitters. Looking upon the matter from an engineering standpoint, as these gentlemen have done, considering that you have a motor at the distant end of a long cable and that you have an alternator at the generating end, then it goes without saying that the sine wave method of transmission must be right. I think that will be a self-evident proposition, as soon as you consider it carefully. If you were to apply an ordinary current wattmeter at Ireland and transmit in to the generator in Canada a given amount of power in watts by the rectangular wave, that is, by the sinusoidal wave, the same amount of power transmitted in the two cases would show much greater received power in Ireland for the sinusoidal wave than it would for the rectangular wave. Considered from the engineering standpoint of the transmission of energy, all the harmonics in the rectangular wave represent waste power.

So far we are dealing with the supposition that you are going to take power out at the receiving end; and that is not practically true, because you do not have a wattmeter in Ireland; you have a delicate instrument which requires about 30 microamperes of current to operate it, and is not the same as a wattmeter. Moreover one does not send a sequence of reversals. The impulses sometimes alternate, and sometimes are successively similar. Therefore it is necessary to introduce some modification in the case and change from the pure case of the transmission of energy to the case of the transmission of intelligence from the wattmeter, which knows no distinction of persons, to the eye which has to be trained to read these signals. As Capt. Squier clearly expressed it, you can find one man who will read those signals and will be able to receive the current at a certain frequency, and another man may not be able to do it. The result is that although it is absolutely certain that the sine wave transmission must be much better than ordinary rectangular transmission for power to a motor or wattmeter, the disproportion is probably not so great, when you come to mixed signals to a siphon recorder. Undoubtedly there must be an improvement. The sine wave with the omission of all the harmonics must have a distinct advantage; but the advantage ought not to be as great

when dealing with a siphon recorder as they would be if you simply had a motor. You have a mixed problem there and it is impossible to get accurate results until you have some machine which will read and decipher standard signals. But there can be no doubt that even if this system were not introduced into practice, we owe much to the authors for the clear and scientific way in which they have presented their results.

MR. DELANY:—Mr. President, in regard to the inquiry relating to speed over the Atlantic cable; as Capt. Squier has pointed out it is a very wide question, depending very largely upon the cable and its insulation and its resistance, and also to a certain extent on the people who are operating it, although there is a standard of safety in cable telegraphy which holds it down to the abilities of any man in the office who is permitted to work the cable. The signals must be plain enough for every man in the office to decipher them, and the speed of the machine, as matter of fact, is independent of the receiver; the speed of the cable is independent of the receiver except to the extent that the receiver is supposed to translate the signals as fast as the machine will produce them, although the machine may run ahead of the man who is transcribing, and of course at the transmitting end, which is worked by macninery, the speed has nothing to do with the operator. Over the 1873, 1874 and 1880 cables of the Anglo-American Company, for instance, the speed does not vary very much. The highest signaling over the 1894 cable that I am aware of, with regular traffic in the middle of the day, has reached 252 letters, or 50 words per minute, with the traffic just as it came; and no cable traffic is easy except perhaps a newspaper report.

PROF. OWENS:—Mr. President, I have had the fortune of seeing something of this apparatus, and I wish to say that I also appreciate the presentation of the paper here. I think it can be clearly seen that the authors have demonstrated the advantages of the sine wave. Why the alternating current has not long ago been applied to the transmission of energy for distributing intelligence, I fail to see. One of the most interesting points in the cable, to me, is the apparently established direct line of relation between speed and electromotive force. The second important point is the advantage of the sine wave over a battery wave of the same maximum amount. If nothing more than these two points were proven, as they seem to be, I should consider the paper of extreme benefit. The apparatus as such is very perfect and it alone would seem to be a great advance as far as I am familiar with the subject. We are indebted to the authors for presenting the result of their work here.

[COMMUNICATED AFTER ADJOURNMENT BY DR. BEDELL.]

A point has been well brought out by Dr. Crehore in regard to code, and that is the matter of good and bad letters. The former are cross letters and the latter are letters that have signals in the same direction. The fact has also been pointed out by Mr. Delany that it is generally found that the speed is restricted not by the cross letters but by the bad letters with successive impulses in one direction. In my remarks, a wave-form coming gradually to zero was indicated which would help these bad letters. The variation being always sinusoidal, it is likewise well adapted to the cross letters; but the greatest advantage comes in the bad letters by avoiding such bad effects as accompany the sharp reactive point which occurs between successive impulses of one direction, obtained from a rectified alternating current.

I may add that from the fact that a higher voltage may be permissible with sinusoidal direct current impulses, on account of reduction in the strain upon the cable, resulting from the elimination of sudden inductive reactions, it does not follow that a higher voltage is necessary when such impulses are employed.

With reference to the remarks made by Dr. Crehore, that sinusoidal impulses of one polarity (curve *c*) may be considered as waves of double frequency, Mr. Steinmetz has clearly shown that a rectified alternating current gives a series of impulses of double frequency which are non-sinusoidal, so that only their fundamental harmonic is available and the effective value is much reduced from what it would be were the waves sinusoidal. It may be that no one fixed wave-form will possess all the virtues and be the best for every letter and every code, but we may study the difficulties and minimize the weak points and accentuate the strong, adapting our wave-form to meet the conditions.

THE PRESIDENT:—If there is no further discussion the Committee on Resolutions is ready to report. I will ask the Chairman to read the resolutions.

The Chairman of the Committee, Mr. Calvin W. Rice, presented the following resolutions:

MR. PRESIDENT:—In accordance with the motion of Mr. Dunn, and the action of this meeting, we, the Committee appointed by you to propose such resolutions as will fittingly acknowledge the courtesies and hospitality, received at the hands of the Philadelphia Reception Committee, and our brethren in Philadelphia in general, do hereby report, and present for your consideration and adoption the following expressions of appreciation.

RESOLVED:—That we hereby express to the members of the Philadelphia Local Committee, to the members of the Institute in Philadelphia, the Franklin Institute, to the Trustees of the Drexel Institute, the Morelton Club, the Manufacturers' Club, the William Cramp & Sons Ship and Engine Building Co., the Baldwin Locomotive Works, and to such other Corporations as have given us the freedom of their establishments and contributed to our entertainment, and

to all other to whom we are indebted, our sincere appreciation of and thanks for the many courtesies they have on every hand extended. These courtesies and hospitality but uphold the tradition of the city of our hosts for the kindness of its welcome. And be it further

RESOLVED :—That these resolutions be spread upon the records of our society, and suitable copies be sent to the Chairmen of the Committees and the representatives of those whose invitations it has been our pleasure to receive.

CALVIN W. RICE,
GEORGE F. SEVER,
W. W. KER.

MR. DUNN:—Mr. President, I move the adoptions of these resolutions by a rising vote.

THE SECRETARY:—Before the vote is taken I would suggest that the resolution be subject to amendment by the insertion of certain names that may have been omitted by inadvertence, in order to make it complete.

MR. RICE:—I accept the amendment.

Seconded and carried.

THE PRESIDENT:—The next paper will be "Telephony over Cables and Long Distance Air Lines," by Dr. M. I. Pupin.

[See p. 245, April, 1900, Issue.]

Discussion.

The President:—Seven years ago the electrical fraternity was startled with a paper on Ocean Telephony. But seven years have passed and we have not yet telephoned across the ocean. The present paper differs from this other one, which was read by an Englishman, in that, in the first place it makes no such extravagant claims as ocean telephony, and in the second place it verifies by actual experiment, the application of a very interesting theory. Papers like this, and the preceding one, show what good results can be accomplished by a careful and intelligent application of correct theory. Such papers reflect great credit on the Institute. The paper is now open for discussion.

Mr. Steinmetz:—Mr. President, I have been very much pleased to listen to this highly interesting and extremely important paper, which marks a decided advance in the art of telephony, as I believe. Now, coming first to a comparison with previous propositions for improving the method of telephony over cables, there is an essential difference between the present case and the previous ones. In the latter, if I remember rightly, it was proposed to distribute inductances along the cable, these inductances to be shunted across the cable. The capacity of the cable and the static capacity act as a shunt across the line. If you want to compensate for the effect of capacity by self-induction, or self-induction by capacity, one must be in shunt and the other in series. That is to make up for the electrostatic capacity of the cable. That is the case here. The phase relation and frequency will remain the same throughout the whole line. This was not the case with the previous proposition. The problem of transmitting alternate currents leads to two very distinct phenomena and problems, that of transmitting very large powers at very low frequency relatively, and high voltages, with the so-called electric power appliances, and then the transmitting of very small powers at very high frequencies at very low voltage. That is telephony. The theoretical aspect of the problem is the same, but they have to be conducted entirely different. The solution of the problem in the one case is entirely inapplicable to the other case. Theory has to go ahead of investigation, except by mere luck in an individual case you find a solution, and in the next case you reach the same solution and it is entirely wrong. We have found means to compensate for the effect of self-induction by synchronous apparatus. Self-induction is not an objection any more; it is rather an advantage. We have a similar problem in the system of telephony, only there it is not the self-induction which is very small in the ordinary telephone, at the frequencies and voltages in current use, but it is the capacity which is the dangerous objection. The attempt to use the solution which is satisfactory in power transmission would not be fair because the two conditions are entirely different. The shunt across is en-

tirely unsatisfactory and makes the problem worse, it spoils what little transmission of speech we can get. In America we have investigated the transmission at very high voltages and at relatively low frequencies. There is a certain value in self-induction but it is not at all essential in most cases to have exactly this value. You can get half as much and still the transmission is very much improved over what it would be without the self-induction. The more you put the self-induction in the better it becomes.

Referring to the second part of the paper, the mathematical side, I have not read it yet, so I cannot say anything about it. If any further suggestions occur to me I shall communicate them in writing.

DR. CREHORE:—Mr. President, I would like to make one inquiry. It occurs to me that in looking up the proportions to form a distortionless circuit the value of i or the reduction required is invariable; that if you were to send a sine wave into the cable the energy that you get through is necessarily very much reduced from what it would be without the induction. I would like to ask Dr. Pupin for a comparison of the amount of energy that he gets through this 250-mile cable by sending a constant voltage, say of 30 to 50 volts. I would like to form a comparison between the amount you get through the cable when you have those coils in, and when you do not, because it seems to me very important as to the distance that you will be able to cover.

DR. PUPIN:—The ratio is 1 to 10,000.

DR. CREHORE:—The ratio between the energy you would receive and otherwise?

DR. PUPIN:—Yes. By making a certain arrangement you can get it constant within practical limits. In this particular case the ratio of the current put in at one end and the current received at the other end is 50 to 1. Two per cent. of the current that is put in at one end is received at the other end when you put the coils in, and of course that is all that is needed for telephony over that length. If you did not have the coils in, instead of 1 to 50 you would have 1 to 125,000.

DR. CREHORE:—You mean you would get a larger amount with the coils in?

DR. PUPIN:—Yes; very much larger. I say 1 to 125,000. I could not get any current through at the other end at all that I could detect with the telephone. I believe you do not get anything through to speak of.

DR. CREHORE:—Sending a simple sine wave?

DR. PUPIN:—Sending a simple sine wave by means of the alternator; that is, using about 15 volts at one end. This calculation refers to about 625 periods per second.

PROF. FRANKLIN:—What is the condition of this circuit with regard to the distortion?

DR. PUPIN:—The attenuation constant is the same for all frequencies, and therefore the circuit is distortionless. If there was any difference at all in the relation between the attenuation and the frequency I did not notice it.

PROF. FRANKLIN:—You did not take precaution beforehand to satisfy the conditions.

DR. PUPIN:—Yes. I did not want any distortion. I could have detected it experimentally up to about two per cent. on an average. Up to that limit there is no dependence between the frequency and the attenuation. If it is anything less than two per cent. it does no harm.

MR. STEINMETZ:—Since they have been speaking of distortion, I desire to sound a note of warning. As I said before, the solution in telephony is entirely different from that in power transmission at low frequency. That does not mean that the proper method of alternating current transmission is to put in as much capacity as to make it distortionless. Take a telephone cable and impress it with the ordinary electro-motive force; then you will require a very large impressed power to get the same current out of the cable without inductance.

DR. PUPIN:—I would like to correct a statement which our worthy president has made. It is not an error on his part, but rather a misunderstanding. He said I did not make a claim to telephony on an ocean cable. I do decidedly make that claim.

THE PRESIDENT:—You did not make the claim in the paper.

DR. PUPIN:—I did not make it in this paper, because I reserved it for another paper which I expect to bring very soon before this INSTITUTE, in which I shall discuss the cable problem in all its details. But I do now state decidedly that I am convinced that telephoning over a cable of reasonable length, say 1,000 miles to start with, is quite possible and nothing at all extraordinary.

PROF. FRANKLIN:—I would like to ask Dr. Pupin a question, and that is, why not apply this method which you have been working upon to simply increasing the possible speed of telegraphy? It applies to that equally with telephony. Why telephone across? Why not apply it to increasing the speed of signaling.

DR. PUPIN:—That goes without saying. It will help telegraphy as well as telephony. Of course it would increase the speed of telegraphy. You can take a distortionless loaded conductor like the one described in this paper and transmit five or ten different messages over the same wire. That would be even more important than telephony, but I don't know that it would be as interesting from a scientific point of view.

THE PRESIDENT:—When I said that Dr. Pupin did not make any claim to ocean telephony I meant to compliment him; I meant to say that he claimed no more than what he had really accomplished, and that it was in this that his paper differed very radically from the other one to which I referred. Concerning

ocean telegraphy, or at least trans-Atlantic telegraphy, it should not be forgotten that in telephoning east and west there is another factor which enters, and that is that the business days in London and New York, for instance, differ by five hours and do not overlap for a sufficient length of time to make it pay to have a cable for telephoning across the Atlantic unless such a cable could also be used at other times for telegraphing. To simply have a cable for telephony I am afraid would hardly pay, because the ti ne of utilization would only be about two or three hours out of the 24. This does not apply to telephoning north and south.

DR. CREHORE:—I would like to inquire whether I am anticipating too much to ask Dr. Pupin whether he is prepared to show a form of cable which he could put such coils into or indicate how a cable is to be constructed for submarine work, or whether he chooses to reserve that for the paper which he intends to present in the future?

DR. PUPIN:—No; it is no secret. I did not talk about it, because I have not yet sufficient experimental data on that particular form of cable, but it is a cable of the same kind as the one discussed in this paper. There is only this distinction, and it is only a distinction in degree and not in principle at all. I said a little while ago that on a land line of 2,000 miles, say between here and New Orleans, if you wanted to introduce coils at a distance of two miles it would be sufficient, but if you have a cable where the capacity is large, then the coils have to be placed at much smaller distances apart. I made a calculation for a particular form of cable, say three-tenths of a microfarad per mile and four ohms resistance per mile, and in order to give the cable a sufficiently small attenuation constant for 750 periods I introduced inductances so as to give three-tenths of a henry per mile. I made the reactance coils smaller. I wound the core two inches and a half external and one inch internal diameter and six inches long with very fine iron wire. That is where the whole trick comes in—to have fine wire. It is necessary to have iron wire two mils in diameter. I am informed by some manufacturers of iron wire in Worcester, Massachusetts, that they would fill such an order if I wanted it at once. This is very fine Swedish iron wire. They can draw it very easily down to two mils diameter. You wind two coils in inductive relation to each other, each 40 turns, copper wire, and then you place them eight coils per mile. That is at a distance of between 600 and 700 feet apart. Coils like that can go right into the sheathing of the cable. It is all a question of Foucault current losses in the iron. The Foucault current losses can be reduced to a very small amount. I calculate that 25 coils like that, with a frequency of 750 periods, would be equivalent to adding one ohm to the line. So that form of cable is a practicable form. Instead of having them 700 or 800 feet you can make them a little more frequent.

MR. HOMMEL:—It appears to me that the main point just at

present is to see whether it is practicable to telephone for any such distance through the capacity of an ocean cable and resistance, and if it is, the working out would be a matter of detail. Even if the coils could not be made in just this manner, it appears to me it would not matter. If they were a little larger there could be some mechanical arrangement devised so as to take the strain off the coils, and while this arrangement as well as the other would undoubtedly make the cost of manufacturing the cable higher, probably the income from being able to telephone across would warrant the expense; and it appears to me the main point would be to find out whether it is practicable to telephone any great distance over an ocean cable by means of self-induction added at intervals as shown.

DR. PUPIN:—But one more remark. Nobody cares so much for ocean telephony anyhow. It is not so very important. It is very interesting from a purely scientific point of view, but whether it is of so very great commercial importance I am not prepared to say. I am rather inclined to think the other way. I think telephony on land lines is the point. We have reached the limit of telephony over land lines. We cannot telephone over 1,000 or 1,200 miles with any sort of satisfaction. The telephone men themselves tell me that it is a somewhat unsatisfactory business to telephone between St. Louis and New York. You have got to repeat your sentences very often. The lines are too expensive. The circuit between New York and Chicago costs for copper alone $250,000. Now, supposing you wanted to extend the limit of telephony and wanted to go to San Francisco or to Kansas City, unless you spend four or five times as much per mile on the circuit you cannot telephone at all. Then you have other considerations—the weight of the wire, etc.—and according to the views of the telephone men themselves it is impracticable to carry on the telephone business over a distance longer than 1,200 miles. By spending a few dollars for these coils, at proper distances apart, I would undertake to build a line between New York and New Orleans, although I am not a practical engineer and I do not care so very much for commercial work, but just for the sake of showing what could be done I would undertake to build a line between New York and New Orleans that would be four ohms per mile; that is twice the resistance per mile of the standard wire between New York and Chicago. I think that this is the really important problem—the problem of extending the limit of telephony over land lines.

THE PRESIDENT:—If there is no further discussion we will go on with the next paper. The title of the next paper and the last one is "Notes on Synchronous Converters," by Prof. R. B. Owens, of Montreal.

[This paper will be printed subsequently.—EDITOR.]

A paper presented at the 151st Meeting of the American Institute of Electrical Engineers, New York, February 26th, 1901. President Hering in the Chair.

IMPORTANT EUROPEAN ELECTRICAL AND ENGINEERING DEVELOPMENTS AT THE CLOSE OF THE NINETEENTH CENTURY.

BY WILLIAM J. HAMMER.

The author of this paper has found it impossible to do even scant justice to those subjects, which he has selected, without going somewhat fully into details in each case. He will not attempt to read it in full, but endeavor to present the salient points as the lantern slides are shown.

The Telephonograph.

The telephonograph, or, as it is sometimes called, the "telegraphone," the "microphonograph," and the "magnetophonograph," is the invention of a Danish electrical engineer, Mr. Waldemar Poulsen, of Copenhagen, Denmark. This beautiful and ingenious instrument was considered by all those who had the opportunity of seeing and testing it at the recent Paris Exposition to be the most interesting scientific novelty there exhibited. In principle it is so simple it seems remarkable, that with all our familiarity with electricity and magnetism, such an invention should not have been made long ago. The apparatus, which is indicated in Fig. 1, consists of a drum of brass about $11\frac{1}{2}''$ in length by $5\frac{1}{2}''$ in diameter. On this drum, which is revolved by means of an electric motor, is wound 225 turns of steel piano wire, of a diameter of about one mm. Supported above this wire, but not in contact therewith, is a tiny magnet, such as are shown in Fig. 2, letters A and C which are almost natural size. This magnet is attached to a brass support, mounted

on a shaft, so that as the drum or cylinder, carrying the steel wire revolves, the magnet is caused to move from right to left across the drum, being guided by a grooved finger, resting upon the steel wire on the drum, each turn in the steel wire passing consecutively before the poles of the tiny magnet. On reaching the end of the cylinder, an arm mounted on the left side of the frame strikes the tiny lever shown in the illustration, raising the magnet, and causing it to run rapidly back to the beginning again (the carrier being guided by the coarse threaded shaft, shown parallel to the supporting shaft) this operation taking but five seconds. The legs of this magnet are about $\frac{7}{16}''$ long, and

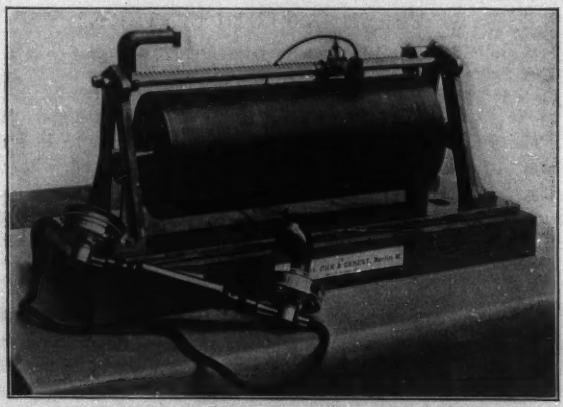


Fig. 1.—Poulsen's Steel Wire Telephonograph.

are wound with bobbins of wire of about the same size as those employed on an ordinary receiving telephone magnet. A cross-section of the magnet is shown in Fig. 2, letter C. It has been found that a horseshoe form of magnet, as shown in Fig. 2, letter B, will not respond rapidly enough, and it is preferable to employ two separate magnets electrically connected, as shown in Fig. 2, letter C. In the ribbon form of telephonograph, the horseshoe magnet shown in Fig. 2, letter D, may be used, but even here two magnets electrically connected are preferable. This recording electro-magnet, which has a resistance of 100 ohms, is connected in circuit with an ordinary carbon telephone transmitter, and a couple of cells of bat-

tery, and preferably with an induction coil in the usual manner. When the transmitter is spoken into, it acts as a tap upon the battery, and causes currents of varying strength, and in proportion to the strength of the sound waves impinging upon the diaphragm, to pass through the wire wound on the electromagnet. Now as the steel wire wound on the drum passes in front of, but not in contact with the poles of the magnet, its varying magnetic field magnetizes transversely the steel wire, and the "lines of force" are permanently recorded therein. After the steel spiral has been filled, which operation takes about 39 seconds at an ordinary speed of talking, and records 100 to 120 words, the tiny magnet is placed at the point where the record first started, and in place of the transmitting telephone with which it was connected, a Bell receiving telephone is attached. The cylinder or drum again revolves, and as the magnetized steel wire passes before the poles of the electromagnet, it forms a species of magneto-

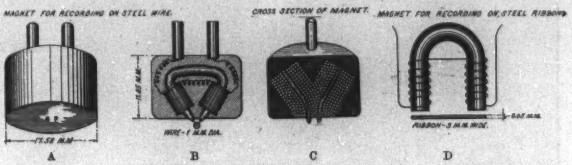


FIG. 2.—Telephonograph Magnets.

electric generator, giving out currents of electricity of a strength and direction corresponding to the magnetization of the steel wire, which correspondingly affect the Bell telephone, and reproduce the sounds and words originally spoken with absolute fidelity. In Edison's phonograph and its modifications, such as the graphophone, gramophone, etc., a stylus is always employed to indent the surface of wax, metal, or other yielding substance. The stylus resting upon such a surface, and being attached as it is to the vibrating diaphragm of the phonograph transmitter, is affected by the dampening effect of the needle or its inertia, and the higher harmonics are more or less destroyed, and there are also false sounds produced, due to the molecular disturbances in the needle and diaphragm itself. Although Mr. Edison has recently made remarkable improvements in the perfection of recording and reproducing by means of his phonograph over his earlier forms, there are difficulties such as I have referred to, which it

has heretofore been impossible to overcome. In Poulsen's telephonograph, however, the tiny magnet not being in contact with the steel wire, the lines of force are silently stored up, and without being affected by external influences. The author has had considerable experience in working with various types of phonographs, and was accorded facilities to examine and operate the telephonograph, both at Paris and at Berlin, and still more recently here in New York. In Berlin, Messrs. Mix and Genest have for some time past been conducting a laboratory for experimental development of the telephonograph, and through

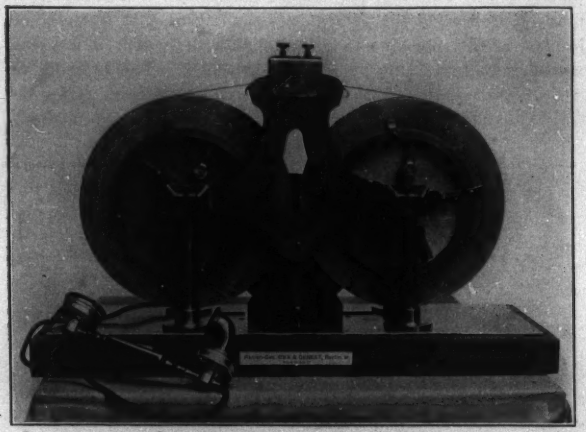


FIG. 3.—Poulson's Band Telephonograph.

their courtesy, and that of Director Zopke, I was afforded the pleasure of visiting this laboratory, and saw some very interesting developments in this promising field. I found the instrument would record and reproduce the most delicate sounds, even breathing and very low whispering, and certain words, which those who have had experience in working with the phonograph know have always been very difficult to record and reproduce perfectly. All have been taken care of most perfectly by the telephonograph. If it is not desired to retain the record made upon the steel wire, the recording magnet is placed at the end of the drum, and connected with a couple of cells of

battery, which supply a constant magnetizing current to the magnet, which entirely obliterates the records which had been stored up in the steel wire, as this wire is passed before the poles of the magnet. A permanent magnet may also be employed for this purpose.

Another type of instrument which Mr. Poulsen has designed, is shown in Fig. 3. This consists of two reels, carrying a band or ribbon of steel about $\frac{3}{16}''$ wide and about $\frac{1}{32}''$ thick. This steel ribbon which may be made of any length and which may be recorded upon for an hour or more at a time, is passed from one reel to the other—the reels being operated by a small electric motor. Above the steel band or ribbon is placed a tiny electromagnet of the form shown in Fig. 2, letter D, which is connected to a telephone transmitter and battery, in the same manner as in the instrument already described, and after a record has been made, is also connected to a Bell telephone, as a reproducing instrument. It is stated that these steel ribbons after receiving the magnetic record could be wound in many layers, similar to a spool or bobbin of ribbon without affecting the record, and that the record could be reproduced thousands of times. It is said that a record has been reproduced 2,200 times and has still been very perfect, and such a spool containing a record could be shipped across the country and placed on another machine, and would reproduce the sounds which originally caused the record, with absolute perfection, and even a rusty wire containing a record has been sandpapered and polished, without affecting appreciably, the record. In Fig. 5, letter D, is indicated: first, how the steel band is magnetized by the obliterating magnet, then by the varying field of the recording magnet, and finally, by the reversal in direction. The Poulsen telephonograph in its ordinary form does not speak louder than an ordinary Bell telephone. I would suggest the employment of Edison's "electro-motograph" or "chalk" telephone receiver, by means of which it could be made to speak very loud. (An audience of 5,000 has been able to hear perfectly this Edison's loud speaking telephone). Mr. Poulsen has suggested a number of other methods by which the sound could be augmented. It is claimed that by increasing the speed during reproduction, over that of the recording speed, that the telephone speaks much louder. This would, however, tend only to increase the pitch, and not improve the volume of the sound. Other methods suggested by Mr. Poulsen are indicated in Fig. 5, letters A and C. They

consist in substance of methods for causing one transmitter to make a number of records on separate steel wires or bands which, on repeating, cause the various reproducing magnets to simultaneously affect the one telephonic receiver. It has also been proposed to utilize the telephonograph as a talking newspaper. In Fig. 4 is shown a method which it is proposed to employ. As the steel ribbon which, in this particular form is endless, and which is receiving the record, passes from one reel to the other, as indicated by the arrows, it passes consecutively before each of the receiving magnets, which are shown in horseshoe form, but which may also be single pole, and the subscribers, whose telephones are attached to these magnets, are thus constantly being

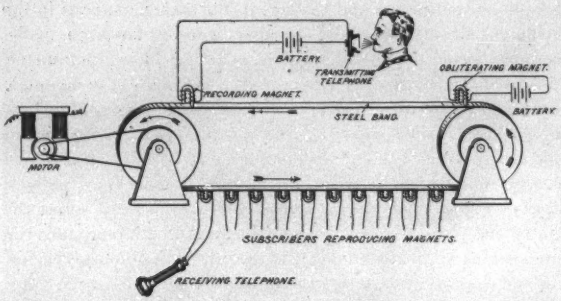


Fig. 4.—The Talking Newspaper.

supplied with the latest news of the day, stock quotations, etc. After the ribbon or band has passed before these magnets, the obliterating magnet wipes out all of the magnetic lines of force stored up in the steel band, and it then passes on to receive fresh impressions from the recording magnet and telephone. In this connection I wish to say that in Budapest, I recently found a talking newspaper system being run in connection with the supplying of music, and talking from the theatres by means of the "theatrophone." During the day the subscribers were constantly being informed of the latest news of importance. This service which supplied many thousands of subscribers was independent of the regular telephone service. I also remember equipping the Theatrophone Co. in Paris in 1889 with two Edison phonographs for a like purpose—this being the first attempt in this direction.

Many suggestions have recently been made for employing the telephonograph in telegraphic and telephonic work, just as were made many years ago when Edison invented his phonograph. It remains to be seen how important the practical applications of this wonderful scientific instrument will become, but it is self-evi-

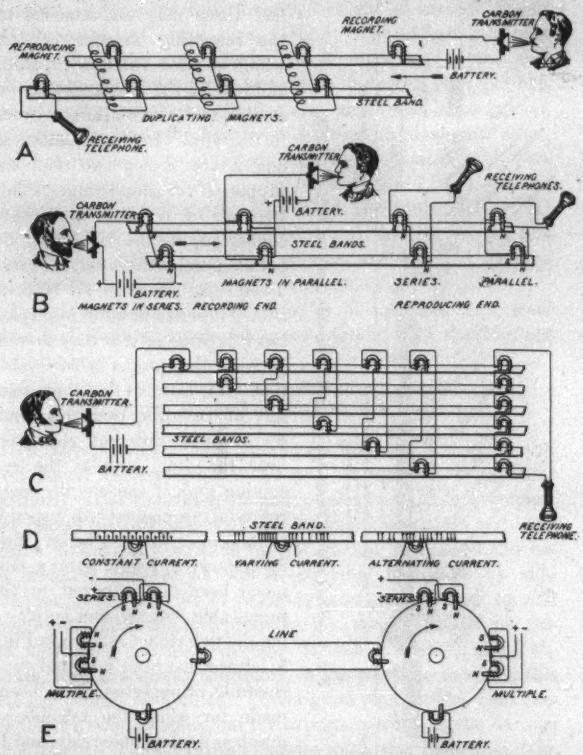


FIG. 5.—Proposed Methods for Increasing Volume of Sound and for Duplexing.

dent that any invention possessing such intrinsic merit, is certain sooner or later to meet with important commercial applications. The author in common with many others has used the phonograph in his office; dictating at his convenience his correspon-

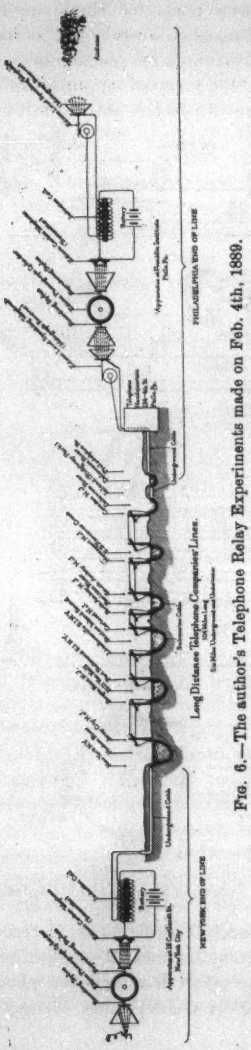


FIG. 6.—The author's Telephone Relay Experiments made on Feb. 4th, 1889.

dence upon the cylinders, from which it was later transcribed by the typewriter. He was recently shown and operated a form of Poulsen's telephonograph, which had three magnets attached to the recording magnet carrier, which enabled him to start, stop, and reverse the movement of the carrier, and also obliterate errors in the wire. In Fig. 5, letters B and E, are shown two methods proposed for duplexing. The two sets of magnets are shown connected, in the one case, in parallel; and in the other, in series. These magnets may all be connected in series, or all in multiple, but it is essential that they should be with the proper polar relation. It is claimed that these two sets of recording magnets send waves of a different character over the line, and at the receiving end of the circuit, each reproducing magnet will respond to its proper wave. I believe the form shown in Fig. 5, letter E, has never been demonstrated to be practicable, but the one employing the two ribbons shown in Fig. 5, letter B, has been operated successfully. Suggestions have been made for using the telephonograph as a telephonic relay, and I am informed that some experiments have been made recently in this direction, in Europe, and it may perhaps not be out of place in this connection, to call attention to the experiments made

by the author in employing the phonograph as a telephonic relay, at the time of his lecture on "Edison and His Inventions," delivered before the Franklin Institute on Feb. 4th, 1889, which experiments were described in the *Electrical World* of Feb. 16th, 1889, and other papers, and subsequently more fully described in the *Electrical World and Engineer*, of June 3rd, 1899. The diagram shown in Fig. 6 illustrates very clearly the arrangement of the two phonographs, four telephones, two sets of induction coils and batteries and other apparatus, circuits, etc., and these experiments, constitute, I believe, the first practical form of telephonic relay, which has ever been constructed, and which operated with perfect success over 104 miles on the lines of the Long Distance Telephone Company, between New York and Philadelphia. (It is interesting to note that the sound passed through the air five times, through fifteen separate mediums, and changed its physical characteristics 48 times in transmission.)[1]

[The author here exhibited samples of the steel wire, steel ribbon and magnets employed in connection with the Poulsen Telephonograph.]

The Langen Mono-Rail Suspended Railway.

It is not possible at this time to go into the history of the development of suspended railways. It suffices to say that practically all of the designers and constructors of such systems have feared the oscillations of the suspended carriages, and have resorted to auxiliary carrying rails or guiding rails, the latter being designed to prevent lateral swaying, and take up side pressures. Various types of swinging railways have been termed "mono-rail," although it is probable that the Engen-Langen system, now being installed between Barmen, Elberfeld, and Vohwinkle, near Cologne in Germany, is the only line to which this term can strictly be applied. The original plan for this road contemplated a two-rail track, but the experts called in by the Barmen and Elberfeld municipalities to advise upon the Langen system, finally decided upon the single rail plan, it being decided that the mass of the carriage was so great, and its vibrations so slow, that it would be possible to get rid of unpleasant oscillations without its being necessary to use auxiliary rails. It was believed

1. See *Electrical World and Engineer* of June 3d, 1899.

that guide rails sacrificed most of the advantages which suspended railway carriages presented. Considering certain disadvantages in surface roads, it is claimed that apart from the limits of speed, which points and switches impose, the two rails of surface tracks are themselves detrimental, as they cannot always be kept parallel, or at the same level. The carriages consequently must vibrate, and the permanent structure be affected more or less seriously. On curves in surface lines, the outer rail is raised, care being exercised not to overdo it, and the ratio in the level of the rails varies with the speed. High speed

FIG. 7.—Suspended car passing over Wupper River.

is generally impossible on surface lines, and when elevated structures with double tracks are employed, they are of necessity objectionable from an æsthetic point of view, and they furthermore obscure the light. A mono-rail track will be lighter, and in every way less objectionable. Curves can be managed with but slight oscillations,—in fact, curves with a radii of 50, 25 and 10 metres have been passed over with speeds of 41, 30 and 16 miles, deflecting the carriages by 35, 36 and 27 degs., and still no motion was felt by the passengers. The carriages on the Elberfeld road do not diverge more than seven degrees. The sharpest curve of the track proper, has a radius of 295 feet; and

only where some exceptional accident happens to the structure or foundations thereof, is there any danger of derailment. Prof. Dolezalek of Hannover, after inspecting the Elberfeld line, in March, 1900, stated that such a system might with great advantage be employed at the termini of railways in large towns, where an extra suspended line could be placed over the permanent track, thus utilizing the same area for two railway lines, increasing the carrying capacity of the road, without enlarging

FIG. 8.—Structure above Wupper river and bridge.

the site, and by this means sending the long distance high speed traffic over the elevated structure, reserving the surface track with its complications, for the local traffic. The length of the Elberfeld line: when completed, will be eight and one quarter miles; 6.2 of which passes over the River Wupper, a tributary of the Rhine, which varies in width from 68 to 115 feet. Barmen, Elberfeld and Vohwinkle, which towns the railroad connects, are situated in the narrow Wupper Valley. No satisfactory route existed for a surface road, and it was deemed impracticable on account of the expense and engineering diffi-

culties, to construct an ordinary type of elevated railroad. I was informed by the engineers of the Elektricitäts Aktiengesellschaft (formerly the Schuckert Company) who are constructing the road, and through whose courtesy I was given a special trip over a completed portion of the road at the time of my second visit, on Nov. 12th, 1900, that the total construction expense for the loop track at Elberfeld, amounted to $224,000. per mile, and the total cost of the road when completed would not be over $2,500,000. for the eight and one quarter miles. The accompanying illustrations

FIG. 9.—Supporting structure over Wupper river.

Figs. 7 to 12, and the lantern slides, give a general idea of the construction of the road, and in the main are from photographs taken by me at the time of my two recent visits. The cars are 37.5 ft. long by 6.5 feet wide, and accommodate 50 passengers each, with seats for 34, who enter and leave by two side doors, opening inwardly. A partition divides the car into smoking and non-smoking compartments. Sections of the opposite sides of the car open outwardly, and become a platform across which the passengers can pass to the cars of a train going in the opposite direction, in case of an accident happening, which disables a car. The doors lock automatically, and

the motorman releases the catch. The end platform guard rails can also be lowered so that the passengers can pass into a train following the disabled one. Two telephone wires are attached to the structure, and by means of a bamboo pole, carrying metal clips, connection can be made from any car to the power house, and various stations on the line. Automatic ticket vending boxes are used along the line. The currents supplied to the up and down track are separate, and a large storage battery is installed

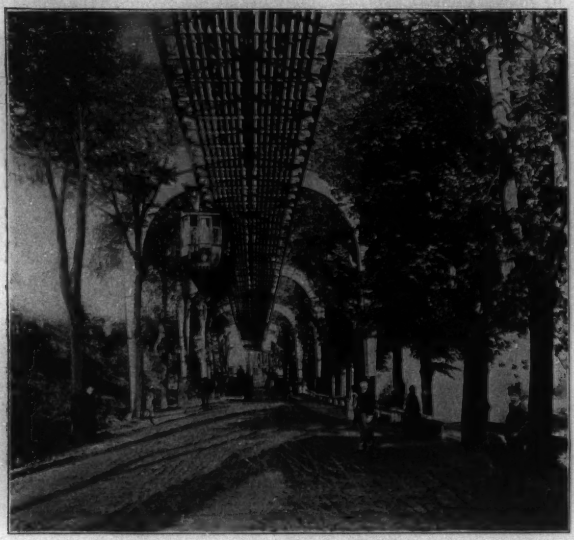


FIG. 10.—Railway passing over roadway.

at the central station. Each train consists of two carriages, but may be increased to four or more, all connected together by rods to secure rigidity. In the front compartment of the first carriage, is the controller for all the motors. As the trains always move in the same direction, it is not necessary to have a controller at the other end of the car. Both ends of each car are, however, equipped with hand brakes and automatic Westinghouse air brakes (supplied with a pressure

of 115 pounds per sq. inch, and having the brake shoes bearing upon the top of the wheels). The cars are also equipped with circuit breakers. Each car is lighted with three clusters of 3/16 C.P. lamps each. Five iron pipes, 36 feet in length and four inches in diameter, running under the floor of the car, are used as air tanks, and also serve to strengthen and support the car. Each car is suspended from two bogies, 26 feet apart, each running on two wheels 35 inches in diameter, which are driven by an electric motor of 36 H. P. by means of spur gearing. The motor is fixed between the two

FIG. 11.—Showing method of suspension, motor, etc.

wheels, and is clearly indicated in Fig. 11. The lower part of the hook-shaped bogie frame is adjustable. The round rail heads form a center about which the entire car can oscillate. The bogie frame is just below the girder member, which bears the rail curve to that center, and the gap between girder and frame, only 0.228, is so small that the wheel cannot jump from the rail, and thus the frame would be held tight by the girder should any part break. The structure is about 25 feet above the street level, and the lowest portion of the carriage

about 15 feet. The weight of the carriage with its load of 50 passengers is estimated as 14 tons, made up as follows:

Two electric motors with complete electrical outfit	6748 lbs.
Two bogies with buffers and cross beams	3960 "
Carriage body with seats, complete	12903 "
Passengers	7700 "
Total	31306 lbs.

This would give a carriage weight, including everything, of 618 lbs. per passenger. The superstructure itself weighs only 700

FIG. 12.—Doppersberg Elevated Station.

lbs. per foot. The supports are placed at an average distance of 100 feet apart. It is proposed to run these trains every three minutes, and at an actual speed of 31 miles an hour; the average speed, including stops, will be about 20 miles. With the automatic block signal system installed, they may be safely operated at intervals of two minutes. As already stated, the two electric motors of a carriage are of 36 H. P. each. They may be connected in parallel or in series in the usual manner, and operated at 600 volts. The current is taken off the contact rail, which is fixed to the obliquely fastened insulators, by a contact

shoe, held by an inclined lever controlled by a compression spring. The contact rail is of iron with a round head, the trolley shoe embracing it and making good contact at any position taken by the carriage. It is estimated that with trains of four carriages, 6,000 persons could be despatched per hour, in either direction. The rails are $4\frac{1}{2}''$ high with a round head, and $2\frac{3}{10}''$ wide with lap joints. It is estimated that it will take two years more to complete the railroad. At the time of my last visit twelve of the 20 stations were already finished, and 26 of the 50 cars completed. Work was started in March, 1898; in January, 1899, a first test of 400 metres was made. On the 24th of October, 1900, Emperor William was given a special trip over $7\frac{1}{2}$ kilometers, from Vohwinkle to Elberfeld. The operation of this road will be followed by engineers with great interest, and it remains to be seen how great an influence it will have upon future transportation problems. I am indebted to the company's engineers and to *Engineering* for the data presented. I understand some 6,000 engineering drawings were prepared in connection with this notable installation.

The Nernst Lamp.

The Nernst lamp is the invention of Prof. Walther Nernst of Göttingen Univ., a leading authority in the chemical world in which his originality had left an important impress before he made his discoveries resulting in the electrolytic lamp. Prof. Nernst informed the author last November at his laboratory in Göttingen, that the discovery of the principles underlying his lamp, had been made during a series of experiments to determine what caused the efficiency of the Welsbach, or as it is called abroad, the "Auer" mantle. More or less secrecy has been observed as to the materials used in the Welsbach mantle, but it is well known that certain metallic oxides, such as thorium, yttrium, cerium, zirconium, glucinum, erbium, and others less known, have entered into their manufacture. Probably the first three mentioned are the ones chiefly used, although the ingredients and proportions have been varied from time to time. These very refractory materials are of a yellowish or a whitish color. They are non-volatile, save at exceptionally high temperatures. Prof. Nernst in his early experiments took certain of these highly refractory substances, such as magnesia oxide mixed with porcelain, which form high-class insulators when cold, but which he found

were electrolytes when hot. These are termed conductors of the second class, or such chemical substances as are decomposed upon the passage of a direct current. An infinite amount of experimentation has been going on all over Europe and America to find the most suitable substances for these electrolytic filaments, or, as they are termed, "glowers" of the Nernst lamp. According to a recent number of the *Zeitschrift fur Elektrochemie* of which Prof. Nernst is one of the editors, a series of tests have recently been made upon samples of glowers composed essentially of the oxides of zirconium, thorium and yttrium, together with certain rare earths. These glowers were all in the form of thin, straight rods, which required a temperature of 900 to 1300 degs. F., to render them sufficiently conducting to start them operating with the electrical currents. The following table gives the results of six experiments with these samples. The three figures in each case, represent the observations in the beginning and end of the experiments, and the mean values. To obtain the mean spherical candle power, multiply the candle power in the table by .78. The watts given is solely for the energy consumed in the glower itself, and to this should be added from five to fifteen per cent. for the energy consumed in the steadying resistance in series with the glower, which is indispensable in the actual working lamp:

TABLE:

Life (hrs.)	Volts.	Amperes.	Candle power.	Watts per candle.
231	184—191	0.21—0.192	28.5—24.5	1.35—1.50
	186	0.206	28.1	1.37
308	181—201	0.22—0.19	30.5—27.0	1.30—1.42
	190	0.20	29.8	1.35
447	190—203	0.41	64—57.5	1.21—1.45
	188	0.41	58.7	1.37
249	188—205	0.41—0.40	67—70	1.12—1.17
	192	0.40	65	1.20
522	184—196	0.85—1.0	123—130	1.27—1.50
	189	0.96	129	1.41
334	180—192	0.38	57.7—58	1.19—1.26
	184	0.38	53.5	1.31

The efficiency of incandescent illuminants, as far as radiation goes, depends simply upon the temperature. The carbon filament in an incandescent lamp is structurally too weak, and has too low a specific resistance to stand very high temperatures.

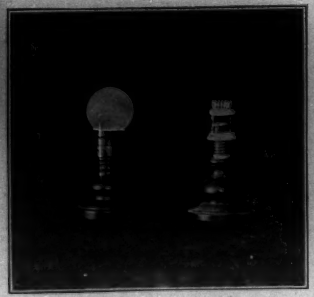


FIG. 14.—Standard Type German "Automatic" Nernst Lamp.

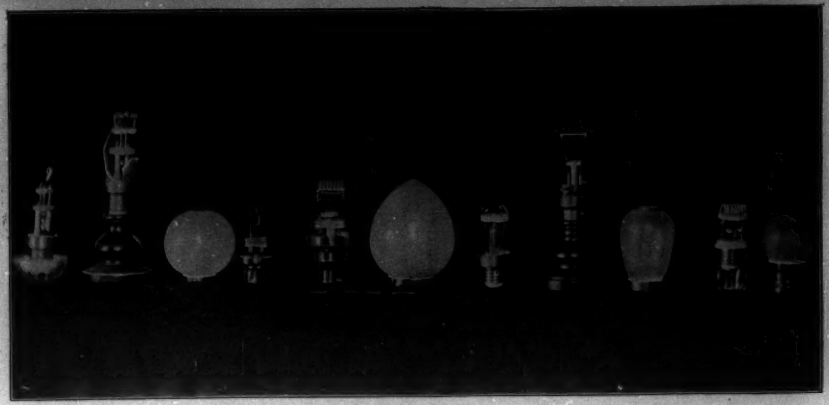
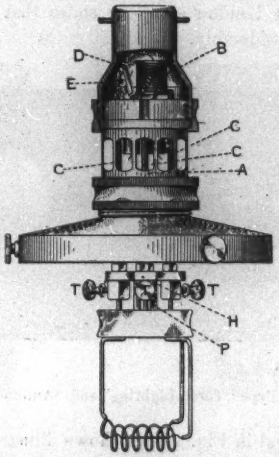


FIG. 13.—European Types of "Torch Lighting" and "Automatic" Nernst Lamps.

FIG. 15.—"Replacement" Piece and Socket (English Type) "Torch Lighting" Nernst Lamps.

FIG. 16.—"Replacement" Piece and Socket (English Type) "Automatic" Nernst Lamp.

The blackening of the globe of an incandescent lamp is indicative of its rapid disintegration, and of the fact that its highest practicable temperature has been reached. Probably the most refractory substances thus far used as illuminants are zirconium, used to replace the lime in the lime light, and the oxides of the so-called rare earths already referred to, used in the Welsbach mantle and the Nernst lamp. It is a well-known fact that the Welsbach incandescent gas mantle falls off in candle power very rapidly. I believe the loss is about 25 per cent. in the first 60



Part Section.

FIG. 17.—Standard Type English "Automatic" Nernst Lamp. 100 Volts. 50 C. P.

hours. So closely is the composition of the Nernst filament or glower related to the Welsbach mantle burner, that it is an interesting question as to what extent the Nernst lamp will fall off in its efficiency. The greatest difficulty experienced by the manufacturers has been the proper clamping of the filament. I have examined some of the platinum connections after considerable use, and they seemed to have been eaten away, and even the glower itself is slightly diminished in thickness and become crystalline near the anode or positive pole in lamps run on a continu-

NOTE.—Figs. 15, 16 and 17 are republished from the London *Electrician*.

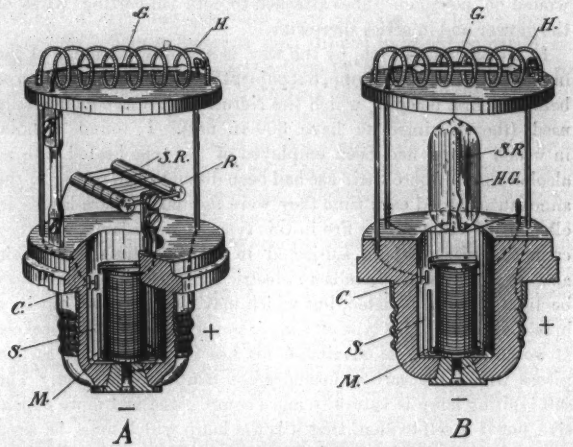
ous current. Many experiments have been made to obviate this difficulty, such as forming a blob of refractory material around the platinum connections, and bringing the platinum wire to the surface to reduce somewhat the temperature by radiation. There seems to have been also considerable difficulty caused by expansion, which the London Nernst Company claims to have obviated by running a platinum wire from the end of the glower through the loop in the supporting wire, enabling the platinum to slide back and forth in this loop. The end of the platinum wire is bent down, and attached to the supporting wire below the loop, and is shown in Fig. 16. The London company states that this has lessened the breakage considerably.

A B

FIG. 18.—English Type "Torch Lighting" and "Automatic" Nernst Lamps.

In Fig. 18 A and in Fig. 15, are shown illustrations of the simplest form of Nernst lamp, of the type manufactured by the London company. This lamp, which is of 16 C. P. at 100 volts, requires an alcohol torch, or a match to heat up the glower at starting; the globe of the lamp is open at the bottom to permit of this preheating. The glower is a tiny white filament scarcely as thick as a common pin, platinum wires wound around the ends attach it to the supporting wires which are of nickel, the junctions to the glower being covered with blobs of a substance similar to the glower body itself; below the glower is shown a triangular piece of unglazed biscuit porcelain, upon which is wound a fine platinum wire called the "steadying" resistance, connected in series with the glower which has a tendency to run to excessive temperatures; and by reason of its rather high negative tempera-

ture coefficient renders such resistance necessary. It will be noted that the porcelain is hollowed out on each of the three sides, so that the platinum which has a large positive temperature coefficient rests only on the edges of the triangle. In the earlier forms it was found that the flat surfaces conducted off the heat of the platinum and it took time to heat up the porcelain and therefore it would not act as an automatic regulator and increase its resistance properly and quickly. The nickel supporting wires already referred to, pass through the triangular piece of porcelain, terminating in eye pieces which engage the hook connections in the



G.—Glower. H.—Heater. S. R.—Steadying Resistance. R.—Rods of Porcelain. C.—Contact. S.—Spring. M.—Magnet. H. G.—Hydrogen Gas.

FIG. 19.—Standard Types Automatic Nernst Lamps shown at Paris Exposition, 1900, and as used in Germany.

base of the lamp. Thus the glower and steadying resistance and their supports represent the renewable portion of the lamp—or, as it is called: the "replacement piece." It is illustrated in Fig. 15.

In Berlin and other places iron wire was extensively employed owing to its peculiar properties, and in order to prevent oxidation and make it operate successfully it was employed in an atmosphere of hydrogen gas. Although I saw many lamps employing

this iron resistance, the tendency abroad now seems to be to do away with its use and employ platinum or some special alloy instead. In Fig. 19, B, is shown a German type of Nernst lamp such as was exhibited at the Paris Exposition in which iron steadying resistance is shown sealed in a glass globe containing hydrogen gas. In Figs. 14 and 19 A, are shown A. E. G. German types of lamps employed in Göttingen and Berlin which show a platinum steadying resistance wound over two rods of unglazed biscuit porcelain, and in Fig. 13, (fourth lamp from right end) is shown a Hungarian type of lamp (Ganz & Co's) where special resistance wires are wound on porcelain tubes attached to both supporting wires of the glower and in series therewith.

In Göttingen—which, by the way, is not only the home of the inventor of the Nernst lamp, but enjoys the additional distinction of being the first place in which the Nernst lamp was commercially used (they claimed to have 300 in use). I found a hotel in which lamps had been employed of the type heated with an alcohol torch, where their use had been discontinued owing to the annoyance caused each time they were lighted. There is also an element of danger from fire in this type of open lamp, and they cannot be placed where subjected to a strong draft. Remarkable as it may seem, here is an electric light which not only may be lighted with a match, but which may also be blown out by a breath of wind. This type of lamp is much more apt to be broken. It would of course be unsuitable for use in mines, or in certain places where the carbon incandescent lamp can be used. The self-igniting lamp is naturally more complicated and more expensive, but it is self-evident that it is the lamp which must be used as a rule. Nernst lamps of this type are illustrated in Figs. 16, 17, 18 B, and 19.

To explain the operation of the automatic or self-lighting type of lamp, when the current is first turned on, the heating coil shown in Fig. 19 is alone in circuit, as the glower, steadying resistance, and cut-out magnet, which are all in series, form a shunt around it of infinite resistance; the current passing through the heating coil soon makes it red hot. The glower or filament of refractory material is heated by radiation and convection, from the coil; until its resistance lowers sufficiently for it to become a conductor of electricity, (four glowers of different C. P. are shown in the foreground in Fig. 13). The moment this happens the current also passes through the tiny electro-magnet inside of the lamp base shown in

Fig. 19 A and B, and which is in series with the glower, and which, in attracting its armature to it, opens the circuit of the heating coil leaving the filament or glower only in circuit with its regulating or steadying resistance and the magnet winding. It takes approximately 10 seconds for the lamp to light up after the circuit has been closed, although I have frequently timed lamps where they have taken as high as 40 seconds to light up. It is stated that the glower of the Nernst lamp must be heated to 700° C. before it becomes a conductor of electricity. The "heater," as it is called, consists of a thin cylinder of porcelain, around which is wound a very fine platinum wire, perhaps .03 to .04 mm. in diameter. The cylinder is then dipped in liquid porcelain, and after drying is bent in a spiral form by wrapping it around a rod while it is being heated by means of a blow-torch. There are usually from five to seven turns in this spiral.

The perishable portions of the Nernst lamp—*i. e.*, its glower, the heater and resistance—are constructed so as to be easily detached, as in the case of the non-automatic type of lamp, and can be replaced at from one-quarter to one-third of the price of the lamp, so that while the original cost of the lamps is greater than the carbon lamps the replacement cost is less. Replacement pieces for both torch-lighting and automatic types (English) are shown in Figs. 15 and 16. The electro-magnet will of course last indefinitely. In the replacement piece of the London company's lamp, a compression-spring contact is used for one connection in conjunction with two eye pieces of different lengths, which engage two hooks in the lamp base, one long and one short; this makes it impossible to wrongly connect up the lamps.

In the German type of Nernst lamp, illustrated in Fig. 14, and in Fig. 19, the glower is placed in the center of the heating coil. In the London company's type, shown in Fig. 18 B, the heating coil is placed below the glower or filament; in others (see Figs. 16 and 17) it is in the center of the spiral, as in the German type.

The London company were for a long time puzzled in their endeavors to get rid of the buzzing noise of the cutout magnet when operating upon alternating current circuits. It was finally found to be due to the air confined back of the armature, by reason of the form they employed; by cutting the iron away a trifle this was entirely obviated.

The company is now standardizing lamps for 8, 16, 32 and higher candle power for circuits of 100 volts and upwards.

The 220-volt lamps are usually made of 25, 50 and 100 C. P., although I saw some at Ganz & Co's works at Budapest and elsewhere of as high as 160 C. P., which were being tested experimentally.

All of the lamps which I saw in Europe were run on a 200 to 220-volt circuit, excepting a few I saw in London on 100-volt circuits, and as a rule 25 C. P. lamps were used.

In the large types of lamps it was found that the magnet coil was frequently burned out from over-heating, and to obviate this the shell of the socket was perforated, which, however, exposes the connections to some risks of short-circuits, and the present form will doubtless soon be altered.

The fine iron wire connected in series with the filament, which has been considerably utilized in the past, has usually been of about .019 mm. in diameter. This iron wire and platinum wire, which has so extensively taken its place, is used because of the glower lowering its resistance so rapidly when the temperature increases. A very slight variation in the voltage increases very much the candle power of the filament and the strains upon it. The wire is so proportioned that with about a normal current it is heated to a range of temperature of about 450 to 500° C, at which iron has a very rapidly rising temperature characteristic—that is, its resistance increases very rapidly with an increase of temperature caused by an increase of current. Being in series with the filament, a total resistance, which determines the amount of current supplied to the lamp, will be the sum of the glower and of the iron steadying wire, and as one decreases with increase of temperature, the other increases and compensates for it, keeping the sum approximately constant. The iron resistance absorbs about 10% of the voltage. As pointed out by Prof. Nernst and Dr. Spies, according to the law of Kirchoff, all opaque bodies emit more calorific than luminous rays, furnishing what is termed the normal spectrum of an opaque body, but according to the well-established electro-magnetic theory of light all conductors of electricity are of necessity opaque to luminous radiations. It is to be expected, therefore, that as long as electrical conducting materials are used as light-emitting substances in lamps, the bulk of the energy expended upon them will be wasted in thermal radiations and only a small portion will be transformed into luminous radia-

tions. It is impossible to make an efficient lamp with such materials except under the conditions of working at the temperature of the electric arc.

At the Paris Exposition the A. E. G. made an interesting exhibit of the Nernst lamp, and advertised that it had an efficiency of 1.6 watts per candle power, a life of 200 to 300 hours, an E. M. F. of 220 volts and from 25 to 50 C. P. Mr. James Swinburne, in his lecture before the Society of Arts, February 8th, 1899, stated the watts per candle for small lamps, including the steadying resistance, as 1.5 and for large lamps as 1.6. At present the London company, with which he is connected, state that their Nernst lamp has an efficiency of 1.7, including the resistance in series with the filament.

There is undoubtedly a large field for the application of lamps of the Nernst type between the field occupied by the 16 to 50 C. P. incandescent lamps and the arc lamp, and it lends itself to decorative effects equally well with the incandescent lamp. The C. P. of arc lamps is something that has never been satisfactorily determined, and it has not infrequently been the custom in judging the C. P. of arc lamps to "guess at it and multiply by four." In C. P. steadiness, color of light and ability to throw the light down where it is needed and in requiring less attention, the Nernst lamp will doubtless prove superior to the arc lamp. There will be little difficulty in making lamps of the Nernst type of very high C. P. by employing longer filaments, or preferably a number of filaments in series or multiple series, and potentials of 500 to 1,000 volts may thus be employed. Promising as the Nernst lamp undoubtedly is, it will probably by reason of the difficulties in the manufacture of the lamp be a long time before the carbon lamp is entirely displaced, if it ever is.

Dr. Otto F. Blathy, Director of Ganz & Co., Budapest, Hungary, who together with Eggers & Co. control the Nernst patents for Austria and Hungary, told the writer recently in Budapest, that when the Nernst lamp became a commercial article, there would be no more arc lighting. He said that tests made by them showed that for a given number of watts the efficiency of the Nernst lamp was greater than that of the arc lamp, presumably meaning the spherical C. P. Mr. James Swinburne in his lecture, said: "Once the 'Nernst' becomes so general that systems of distribution are laid out to suit it, instead of to suit the carbon lamp, the carbon lamp is 'practically out of running.'"

In this connection it will be remembered that with the advent of the Edison carbon filament incandescent lamp, it was believed that gas as an illuminating agent was doomed, whereas it has been shown that the incandescent lamp exercised a stimulating and beneficial influence upon the gas light, which is more extensively employed to-day than ever. The tendency of all great inventions is rather in the line of building up than tearing down.

It is impossible to operate the Nernst lamp in a vacuum, at all events where a direct current is employed, as being an electrolytic lamp, it is said to be necessary to admit oxygen to re-oxidize the magnesium liberated at the cathode. Where continuous currents are used in electrolytic lamps of the Nernst type, the liberation of ions at the connections produces a serious difficulty. I heard it claimed by some while abroad that the lamp operated more satisfactorily with a continuous current. Others, however, were positive that an alternating current was preferable. One prominent engineering authority went so far as to state to me that he did not believe that the lamp would be a commercial success, except when operated from a storage battery. In one place in Göttingen, which installation employs Körting gas engines and storage batteries, I was told that ten lamps of the self-lighting type had been installed, and in four hours they were all burned out. The actual results at Göttingen where they have about 300 lamps burning, show, I believe, that the open type of lamp did not last over 200 hours, and the automatic or self-lighting type did not last over 100 hours. While I was at Göttingen, a telegram arrived from Berlin requesting the return of all of the new automatic or self-lighting lamps sent them a few days previously (some 300 in number) as there was something the matter with them. As they had already put out about 50 of them, this could not be done. This would serve to indicate that even after the several years of experimenting, the A. E. G. who were the parent company, had not yet succeeded in making a lamp which was a thoroughly commercial article. During the past six months, I have seen the Nernst lamp burning in the following places: Paris, France; Munich, Bavaria; Budapest, Hungary; Berlin and Göttingen, Germany, and London, England, and my own impression is that the American type will shortly lead the way.

The A. E. G. have been for several months past putting out lamps in Berlin. They charge a rental or royalty of three

marks (about 72 cents) per year, and 30 pfennigs (7.14 cents) for renewals.

The lamp globe holder and the butt which fits into the socket are sealed together by a lead and wire seal. I was informed that any of these lamps having the seals broken or any lamps which were carelessly broken, had to be repaid for at the rate of three marks each (about 72 cents.) I was also informed that the users were compelled to give a receipt for the lamps, and every effort was made to prevent the lamps from getting into the hands of other people, and to prevent their being examined.

The Nernst lamp gives a most pleasing light; in color it stands midway between the yellow and red rays of the incandescent carbon lamp and the violet and blue of the arc lamp; it is, however, so dazzlingly white that it is, as a rule, placed in ground glass globes, thus securing much greater diffusion; with a loss in the light probably not exceeding 15 to 18 per cent. I watched carefully the 54 Nernst lamps installed by the A. E. G. in the Café Bauer in Berlin, this being one of their first installations, and the light certainly produces a much more pleasing effect than the carbon incandescent lamps (used in certain places in the same fixtures) and is also superior to the Welsbach mantles used in the same rooms. Arc lamps are also burned in front of the café, so that in this one installation four types of lighting were employed—three of them being electrical.

During my three weeks stay in Berlin, I observed carefully every evening the 54 lamps which were here installed, and which were doubtless on account of their prominent position, of the best type made by the A. E. G. and I noted that there were usually from two to four or five lamps out, and even at times as high as eight or nine out, however with an efficiency approximately half that of a carbon filament lamp a much shorter life may be permissible. It was also quite common—both in this installation and others, especially at the Paris Exposition, where the A. E. G. exhibited about 300 lamps, to see the lamp running with the heating coil in circuit, giving a dull and sickly light.

I have endeavored to give the facts about the Nernst lamp development as observed by me during my recent sojourn abroad of over five months. I have no desire to disparage this remarkable and most promising advance in the electric lighting field and well do I remember when an assistant at Mr. Edison's laboratory at Menlo Park, N. J., in the incipient stages of the de-

velopment of the Edison carbon filament electric lamp, the difficulties met with; which at times seemed insurmountable. There were novel and knotty problems to solve such as the modern incandescent lamp manufacturer knows not of. Personally, I have no doubt of the ultimate solution of the knotty and peculiar problems met with in the manufacture of the Nernst lamp, nor of the immense value this invention will ultimately reach to the owners and the world at large.

In conclusion, without going fully into the history of the art; reference should be made to the work of Jablochkoff, who in 1878 made use of sparks from an induction coil passing from one of the parallel carbon pencils of his "candle" to the other, and thus heating up the kaolin insulator placed between until it became a conductor, and the arc once established remained; being supplied by the dynamo current.

He subsequently used a piece of carbon mixed with syrup at the top of the candle which a current of 100 volts heated until the kaolin became a conductor and the arc was supported.

At the Paris Electrical Exposition of 1881 and in the following year in London, the "La Soliel" lamp was shown in which the arc was formed by drawing rods or wires across the face of a block of marble until it became heated sufficiently to conduct the electricity, when it became incandescent and gave a most beautiful light.

Demonstration:—The author here proceeded to show a number of Nernst lamps burning; illustrating how simply they could be ignited by means of a match and by an alcohol flame; and after they had been burning for some time, showed how they could be blown out by blowing upon and cooling the glower. He also placed a lamp of high candle-power in front of a fan motor to show how readily it would be extinguished, or as he expressed it, "how easily it would catch cold." He also exhibited quite a number of the various types of German, Hungarian and English types of torch-lighting and automatic Nernst lamps and glowers of various candle power in a glass case and showed samples of Mr. Longhan's di-carbide of calcium lamps burning.

The Osmium Lamp.

During my stay in Vienna last October, through the courtesy of Director Gallia of the Auer Company, I was permitted to see several of the new "osmium" incandescent lamps burning, and

although I was unable to secure full particulars about this new and interesting development I learned that the lamp, which is the invention of Dr. Auer von Welsbach, operates at an E.M.F. of 25 volts and shows an efficiency of from .9 to 1 watt per candle. The three lamps which I saw in use were all connected in parallel and operated with key sockets, and differed but little in general appearance from an ordinary carbon filament lamp. The globe was somewhat longer than an ordinary 16 C. P. lamp, and the filament, which was of the hairpin shape, was much longer. It must be used in a vertical position, owing to its flexibility. I was told that these lamps had shown a life under test of 700 to 800 hours. It will be interesting to learn to what extent the low voltage of the lamp and the rarity of the material used in its manufacture will affect its commercial application. It had been intended to show the osmium lamp at Paris before the close of the exhibition, but there was not sufficient time. "Osmium," which was discovered by Tennant in 1803, is a blue-white metallic element and is almost infusible. For a long time it was known only as a crystalline grainlike material; and when fused in the electric arc, as a hard brittle substance unfit to be worked. I was informed in Paris, where I first heard of this lamp, that the successful method of handling this material, which has always been most difficult to work with, was due to a large extent to Mr. Waldron Shapleigh, of the American Welsbach Company, which concern controls the patent rights for the United States. According to Engineer Scholz in his lecture before the German Incandescent Gaslight Co., on Jan. 23, 1901, an osmium lamp after burning 1,500 hours was still intact, and had fallen off in candle-power but 12 per cent.

Its efficiency at starting was 1.45 watts per C. P., and at the end of 1,500 hours was 1.7 watts. It is claimed that as long as the filament remains intact it can be renewed several times. While the present range of voltage for these pure osmium lamps is 25 to 50 volts, a number of filaments can be connected in series or multiple series for higher potentials, and it is proposed to increase the resistance by coating or uniting the osmium with certain oxides. Mr. Scholz refers to a test conducted upon 4-25 volt osmium lamps in series, and 4-100 volt carbon lamps in parallel, the osmium lamp showed a consumption of 0.96 amperes, and the carbon lamp 2.40 amperes, the former effecting a saving of 60 per cent.

A 20 c. p osmium lamp run at 27 volts required 24 watts, and a 20 c. p. carbon lamp required 68 watts, the former effecting a saving of 44 watts, or about 35 per cent.

The osmium lamp was much the coolest, by reason of its higher efficiency. I had hoped to be able to show you an osmium lamp this evening and give some fuller data, but was unable to do so. I have brought with me a number of the foreign types of Nernst lamps for your consideration. I have, also, several dicarbide of calcium lamps, which type have been manufactured to some extent abroad. They are the invention of Mr. Langhans, of Berlin, to whom I am indebted for them. They are shown in Fig. 20. It may interest some of our members to learn that the Allgemeine Elektricitäts Gesellschaft of Berlin, are now

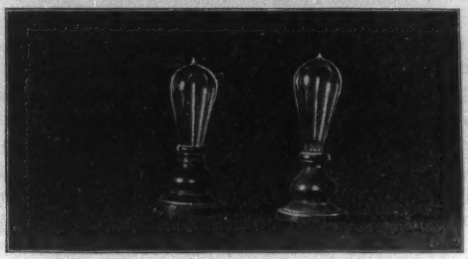


Fig. 20.—Laughan's Di-carbide of Calcium Lamps.

making all their carbon filament lamps without platinum leading-in wires, using, so I have been informed, iron wire, the sealing being done in an atmosphere of carbon monoxide. The A. E. G. purchased the patent from Schott, the well-known glass manufacturer of Jena. I have been presented with one of these lamps, but it did not arrive in time to show it to-night. I am told these lamps give out quickly, diminishing to a dull red. In London I found a company which has been formed for the purpose of "rejuvenating" incandescent lamps. The filaments which have gone off in efficiency and candle power are taken out of the globe and retreated, the globe cleaned of its smoky deposit and the lamp resealed and re-exhausted. I did not learn just how the globes were to be cleaned or what the rejuvenation was to cost. There are also several lamps known as

"watt" lamps being exploited in Europe. They have a high efficiency, and are very simple, and cheaply constructed, and have a life of perhaps 200 to 400 hours. They make no pretense of being long-burning, but rely upon their high efficiency and low first cost.

The Steam Engine and its Competitors.

M. Berthelot, the Chief Chemist of France, and Member of the French Academy to represent science in that body, has recently declared himself against the utilization of steam, which, he declares, is already becoming obsolete, and gives it as his

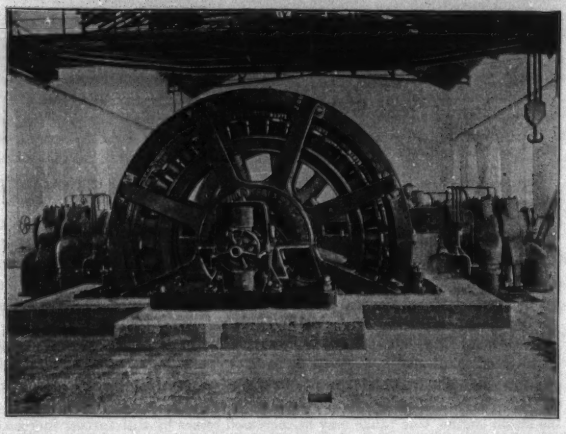


Fig. 21.—Three phase Generator direct connected to 650 H. P. "High Furnace Gas" Engine.

opinion that the future of motive power belongs to gas and petroleum, and that the steam engine will be relegated to museums where other anthropological curiosities from the Stone Age down, are collected.

In December last, in opening a discussion on Mr. H. A. Humphey's important paper, entitled "Power Gas and Large Gas Engines for Central Stations," delivered before the Institution of Mechanical Engineers of Great Britain, Dr. Mond, the well-known chemist and inventor of the Mond Gas Process, stated that the paper which had been presented, appropriately marked

the closing of a century of steam as a motive power, and the opening of a century of gas as a motive power.

The author, while in London several months ago, in speaking upon this subject with Prof. John Perry, F. R. S., and asking for an expression of his views, was told by Prof. Perry that with the development of large types of gas engines, there was no doubt in his mind but that the steam engine would ultimately be very largely supplanted.

In response to a request for an opinion upon this subject, Prof. R. H. Thurston has sent the author a letter which by reason of its very great interest is published *in extenso*:

ITHACA, N. Y., February 22d, 1901.

MR. WILLIAM J. HAMMER,
New York.

My dear Mr. Hammer:

Yours of the 21st is received, inquiring about the relative efficiency of the steam and the gas engine.

The best work, to date, is practically the same for both engines. Each has delivered the net horse-power with a consumption equivalent to about one pound of good coal. The consumption of such fuel for efficiency unity would be about one-fifth of a pound per horse-power, and these engines have thus both attained an efficiency, between the coal pile and the point of delivery, of about twenty per cent.

The steam engine has attained so nearly its limit that further progress under commercial conditions would seem to be likely to be hereafter very slow and to be dependent mainly upon the possibility of increasing the thermodynamic efficiency by extending the thermodynamic range of working temperatures. In the steam engine, this range may be increased either by still further increasing the working pressure at the boiler or by superheating the steam or by both expedients combined. Higher pressures are coming to be available, with progress in the construction of high pressure, presumably water-tube boilers, and we have, in Sibley College work, employed over a thousand pounds without special difficulty and I have no doubt that we can quite as well as did Perkins, two generations ago, use pressures of two thousand pounds and probably more. We are now beginning to find practical methods of construction and use of superheaters for ordinary pressures, and I have little doubt that we will be able to superheat steam of those higher pressures in course of time. These improvements should permit the increase of efficiencies by something like fifty per cent. and bring the consumption of fuel down to three-fourths of a pound of good fuel per horse-power hour, and perhaps within the next generation, if not within ten years.

I am not prepared to say what should be hoped for with the gas engine; but the indications at the moment would seem to be that, as we have a very much larger opportunity to reduce wastes that now characterize the gas engine than to extinguish those affecting the steam engine, more should be expected from the coming years with the former than with the latter. The gas engine has only now come to be a formidable rival of the steam engine and is gaining upon it rapidly. The deduction seems fair, therefore, that the next few years should see the gas engine so much improved as to permit it, for many places and purposes, to become a successful rival. In some directions, as at sea, in the locomotive, and perhaps in some other departments, it is possible that steam may continue to hold its place unchallenged, but this is by no means certain.

It is unquestionably the fact that to-day the gas engine is steadily overhauling the steam engine and as steadily displacing it in many directions. I think it extremely possible that it may ultimately displace it very largely, but I think that the steam engine is likely to hold a place among economically available prime movers for a long time to come, and no one can say what may be anticipated to follow its further improvement by effectively combining a maximum range of pressure and a maximum range of coincident temperature, the one giving maximum mechanical efficiency and the other maximum thermodynamic, the combination yielding what is the main object of selection in practically all cases—production of power with minimum costs on all accounts, production of power with least reduction of dividend-paying capacity.

Yours very truly,

ROBERT H. THURSTON.

It seems quite clear from the above and similar expressions one hears from those qualified to speak, that with all the progress that has been made in steam engine practice, in the utilization of higher steam pressures, superheated and reheated steam, condensing, multiplying of cylinders, improving of boilers, etc., that they will no longer satisfy the demands for an economical source of power, and in this country and all over Europe, a very large amount of attention is now being given to the development of gas engines of large power, and to the development of improved types of petroleum, oil, benzine, and other promising motive agencies, such, for instance, as the sulphur dioxide gas or "$S\,O_2$" Engine, of which I shall have occasion to speak later. The steam engine up to the present has been able to more than hold its own, by reason of its universal adaptability, and its reliability, even with its comparatively low thermal efficiency. During my recent trip in Europe, I visited many of the largest plants for the manufacture of gas engines, and saw large numbers of gas engines in process of construction and in operation, ranging from 250 to 1200 H. P. each. Types of these engines are shown in Figs. 21, 22, 23, 24, 25, 27, 28 and 29. Still larger

ones are under process of construction at the present time. As indicative of the important work going on in this direction, Fig. 22 shows one bay in a shop of a European manufacturer of gas engines. Various types of these engines I will describe later in the paper. One of the most promising developments, and one which will doubtless enable steam to hold its own to a considerable extent, is the steam turbine now being manufactured in

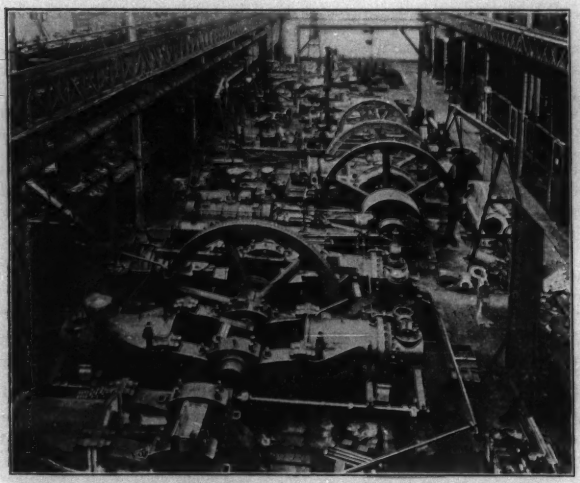


FIG. 22.—Big Gas Engines (Korting) under Construction.

large sizes, both in this country and abroad, and which, by reason of its very great simplicity, slight depreciation and high thermal efficiency, constitutes a steam engine applicable to a very wide field of usefulness and a formidable competitor of the reciprocating steam engine. The Parsons and de Laval types of steam turbines are extensively used abroad, and are being rapidly introduced in this country, where the Curtis steam turbine is also giving most promising results.

Utilization of "High Furnace" Gases and Big Gas Engines for Electrical Purposes.

The utilization of high furnace or blast furnace gases marks an epoch, not only in the employment of gas engines of great power but in the supplying of a new field for the application of electrical machinery. It is estimated that a blast-furnace having a capacity of 100 tons of pig-iron per 24 hours, produces 7,000,000 cubic feet of gas daily, equivalent to 2,800 H. P. If we deduct the power required to drive the furnace proper, there remains 2,000 H. P., which, so far, have been entirely wasted and which, it has been found may be successfully utilized in gas engines, and it appears that only one-sixth to one-quarter as much gas is required as would

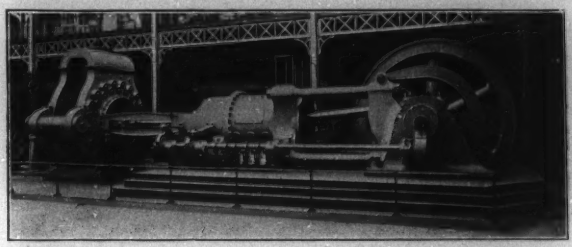


Fig. 23.—1,000 H. P. Gas Engine of John Cockerill Co. of Seraing, Belgium, shown at Paris Exposition. (Connected to double-acting blowing cylinder).

be necessary, when burning the same gases under boilers for producing steam power and furthermore enables us to dispense with costly boilers. Between 25 and 30 years ago it was customary to burn these gases at the top of the stack. They are even so burned to-day to some extent. They were thought to be too poor in quality, and too variable in composition; too full of dust; particularly metallic particles, tending to clog and injure the moving parts; too full of acid matter, and of too high a temperature to enable their use in gas engines; but means have been found by passing the gases on their way from the stack to the engine through pipes and dust pockets in which the particles settle, and through coke and water scrubbers and saw-dust, so that the temperature is lowered, and the gases sufficiently well cleaned. Even at the Friedenshütte Iron Works which I visited in upper Silesia, they

operated successfully with gas charged with 40% of zinc dust, which only required more purifiers. Although some analysis show the presence of sulphuric and phosphoric acids and chlorine, the alkalies and lime probably neutralize their effect, and there is no apparent corrosion. There is little trouble from variations in quality, and gas works well in a gas engine of a quality which ignites with difficulty under a boiler. The first application of the high furnace gas was made in February, 1895 at Wishaw Iron Works, near Glasgow, with a 20 H. P. gas engine, which indicated 15 H. P. when driven with these gases. During the same year high furnace gases were applied on an eight H. P. engine at the Cockerill Iron Works at Seraing, Belgium, and at the Hörde Iron Works in Westphalia, Germany, where they were used in a 12

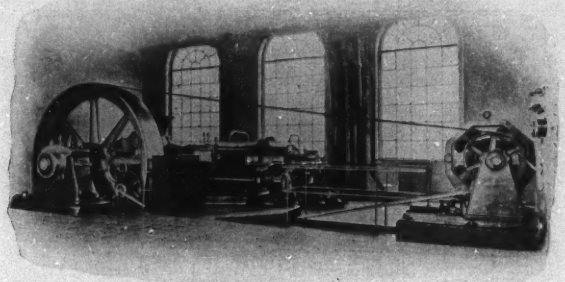


FIG. 24.—Cockerill Gas Engine at Seraing, Belgium, which ran night and day for over two years without stops.

H. P. engine. The first patent for the utilization of high furnace gases in gas engines was taken out the previous year, in May, 1894, by Mr. B. H. Thwaite of England. The high furnace gases are similar in quality to the forms of producer and power gas made by Dowson and other processes, and taken directly from the stack, contain as a rule about 27% of combustible gases, chiefly carbon monoxide, and a little marsh gas and hydrogen; the balance being mainly (about 57%) inert nitrogen. It is estimated that at the blast furnaces in England alone, over 2,000,000 H. P. is annually going to waste, which might be utilized for electrical purposes. The gas engine industry is about 30 years old. During that time, one company, the Otto, has sold in England and Germany alone about 37,000 gas engines, approximating 500,000 H. P. As indicating the development of the large gas engine industry, it is

interesting to note that the Cocekrill company of Seraing, Belgium, and its licensees, has sold in less than a year, 70 engines of the Delamare, Debouttéville & Cockerill system, such as are illustrated in the 1,000 H. P. "Simplex" engine, Fig. 23, which is shown connected to a large double-acting blowing cylinder at the left. This engine develops 650 H. P. when employing high furnace gases. The engine cylinder is 4′ 3″ diameter by 4′ 7″ stroke. The diameter of the air cylinder is 5′ 7″ by 4′ 7″ stroke. The length of connecting rod, connecting two cylinders, is 14′ 5″, diameter 11.8″. Tested without blowing cylinder, this engine showed 573 B. H. P. with a consumption of 123.7 cu. ft. of gas per B.H.P., or with a mechanica

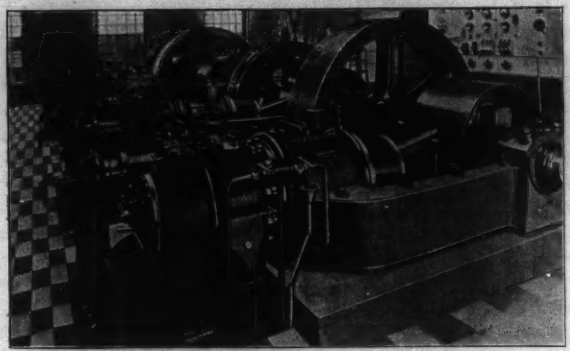


FIG. 25.—A Section of the High Furnace Gas and Electrical Plant at Friedenshütte, Upper Silesia, Germany.

efficiency of 72%, and a thermal efficiency taking the B. H. P., of 20%. With the blower connected, this engine showed 886 ind. H. P. and 725 B. H. P., with a gas consumption of 101 cu. ft. per B. H. P. hour, and a thermal efficiency taking the ind. H. P., of 31.5%. Until recently the speed of these blowers has ranged from 50 to 60 strokes per minute. An ordinary gas engine runs at a speed of 100 to 150 revolutions per minute, according to its size, and giving its maximum efficiency at maximum speed. (According to Kennedy and others a gas engine at one-half load consumes 25% more gas than at full load). I saw recently at Falvehütte in Upper Silesia, Germany, a plant equipped with Horbiger and Rogler valves, enabling these blowers, which in this case were operated by steam generated by furnace gas, to operate at a speed of 80 strokes per

minute. There are several types of valves now on the market, which enables these blowers to be run at a speed, adapting them to be driven successfully by large gas engines.

As an illustration of the great increase in the reliability and the

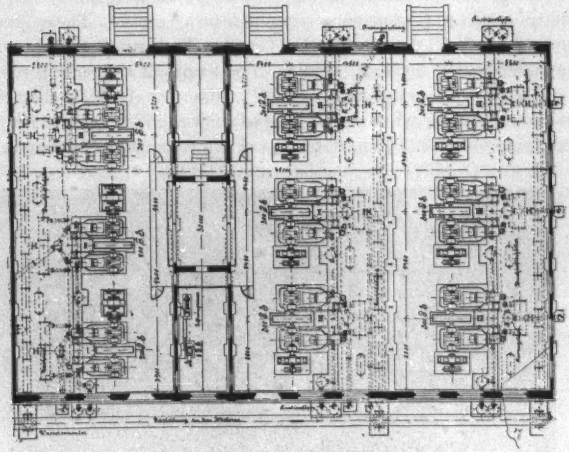
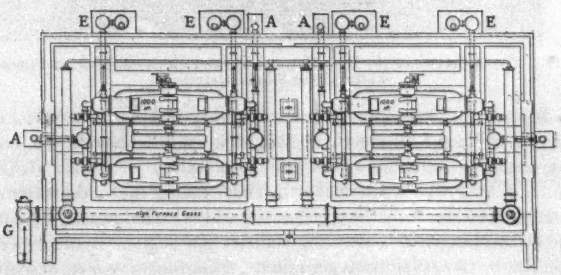


FIG. 26.—Friedenshütte Electrical Installation, employing "High Furnace Gases." (2,400 H. P. when completed).



A.—air. G.—gas. E.—exhaust. M.—gas and air.

FIG. 27.—1,000 B. H. P. Otto-Deutz Gas Engine.

simplicity of the modern gas engine, I call attention to the engine shown in Fig. 24, which I had the pleasure of seeing at the Cockerill Works at Seraing, Belgium. It has been running steadily for over two years, both night and day, operating with high furnace

gas. Prof. Aimé Witz' test showed an average of 181 B. H. P., and it showed a mechanical efficiency of 85 per cent., and consumed 116.5 cubic feet of furnace gas per B. H. P. hour. The thermal efficiency taking the B. H. P. is 20 per cent. The speed is 105 rev. per minute. The cylinder has a diameter of 31.5″ by 39.3″ stroke. Fig. 25 is an illustration of a portion of the gas and electric plant at Friedenshütte Iron Works in Upper Silesia, operated by high furnace gases. At the time of my recent visit to this installation, it consisted of two 200 H. P. gas engines direct coupled to two direct current dynamos, and two 300 H. P. gas engines direct coupled to two alternating current dynamos. The gas engines are of the Otto-Deutz type, driving Shuckert dynamos. They were supplying a couple of hundred arc lamps, and several thousand incandescent lamps, and electricity for power purposes. The total H. P. was 1,000, and at the time of my visit this was being increased to 2,400 H. P. The plant, Fig. 26, shows the entire installation as it will be in operation shortly, consisting of six 300 H. P. engines for power purposes, and three 200 H. P. for lighting. In Fig. 27 is shown an Otto engine of 1,000 H. P. built by this company at Deutz, near Cologne. There are four cylinders of 250 H. P. each coupled direct to a dynamo, the open ends of the cylinders facing one another on either side of it. At these works, I saw many gas engines of great power under construction.

The New Körting Two-Cycle Gas Engine.

In Fig. 28 is shown an illustration of the new two-cycle Körting gas engine of 650 H. P., manufactured by Gebr. Körting, at Körtingsdorf, near Hannover, Germany. This concern, which has long been in the gas engine field, is now building engines of 1,000 H. P. and over; of the 4-cylinder 4-cycle type, as shown in the foreground of Fig. 22, for use with high furnace gases for driving dynamos, air compressors, exhaust fans, etc. In Fig. 28 is shown Körting's most interesting new type of 2-cycle gas engine. This engine, which I saw running in their works during my recent visit, consists of a single working cylinder, containing a driving piston, on each side of which the mixture of gas and air is alternately admitted, exploded, and does its work, reproducing steam engine conditions. Remarkable uniformity of speed is secured by this engine; in fact it is doubtful if it is equalled in this respect by any other type of gas engine at present on the market. Exhaust ports are situated in the center of the cylinder. The

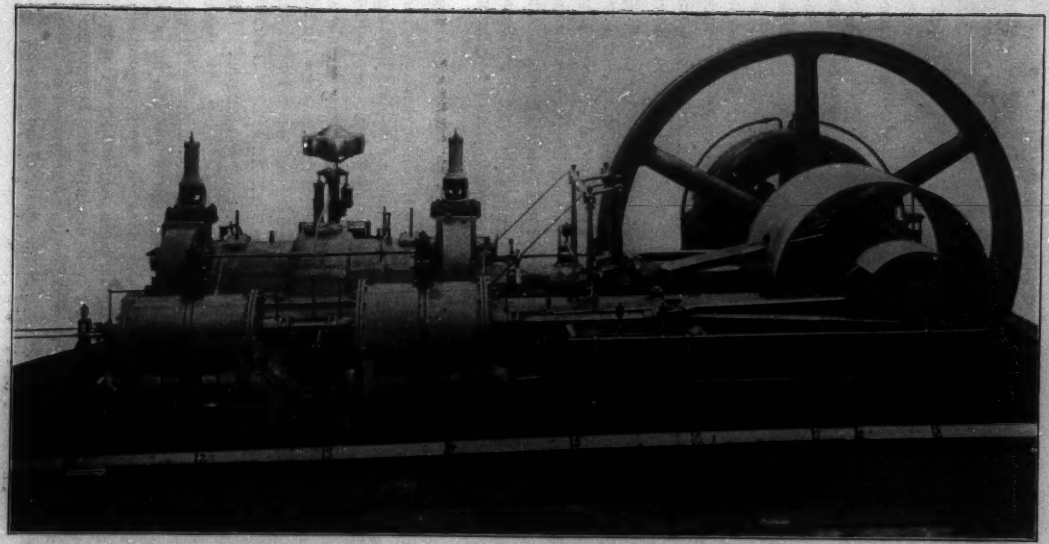


Fig. 28.—Körting Bros. new 2-Cycle—650 H. P. Gas Engine. (Two Twin Engines of this type, of 1,000 H P each under construction.)

piston itself acts as a slide valve to open and close these ports, when it moves in the zones of the dead point at the end of each stroke. Although there is an explosion of each side of the piston, the temperature is kept very low by water-jacketing the cylinder and stuffing box and causing water to circulate through the piston itself. The working mixture is compressed by the main piston on its return stroke to about 12 atmospheres, and when at its dead point exploded by two electrical igniters, one placed close to the piston, and the other close to the inlet valve. On the side of the engine may be seen the gas and air pumps, which are relatively proportioned and connected together. The pumps are provided with piston valves which are operated by an eccentric on the main crank shaft, and serve to direct the gas and air first to one end and then to the other end of the cylinder, performing the same function that is fulfilled by the admission valve of a steam engine, the inlet valves on the ends of the cylinder being merely check valves to prevent back pressure from the cylinder into the pumps. The air and gas arrive, separated from each other, at the valve casing, where they are thoroughly mixed, and enter the cylinder. During about 40% of the stroke, the gas is caused to pass around a by-path, and none enters the working cylinder. During this 40% of the stroke, air alone is introduced in the cylinder, scouring out the products of combustion, which pass through the exhaust, it also forms a layer between the burnt gases and mixture, lowering the temperature inside the cylinder, and making pre-ignition impossible.

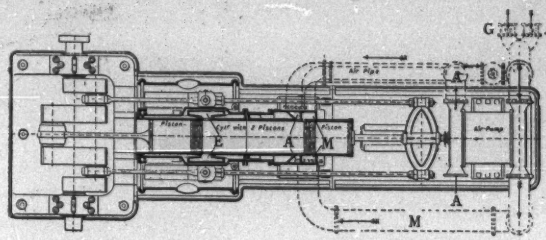
One of the most important features in Mr. Körting's engine, and one which he claims it would be impossible to operate without, is a projection in the combustion chamber, below the inlet valve. This projection is almost semi-circular and of a special form which is the result of considerable experimentation. It is on the concave side of the combustion chamber, which causes half of the moving charge to become deviated at right angles, to the rest of it, thus producing a whirling and rolling motion. This materially assists the scouring action of the air and assists also the thorough mixing of the air and gas, which mixture thus loses all tendency to force itself in the form of jets, into the dead mass of burnt charge and air ahead of it, which it would ordinarily mix with, and cause considerable loss of the new mixture, by its passing out through the exhaust. Were this effect not produced, the loss of gas escaping through the exhaust ports would be so great

as to make the engine as built, uncommercial. The regulation of the engine is secured by the governor acting on the slide of a link motion, which acts on the distribution slide of the gas pump, and according to the position of the slide of the link, the rate of circulation in the gas pump is increased or decreased, controlling the quantity delivered at each stroke. The quality of the mixture remains the same. Mr. Ernst Körting informed the writer that this engine could be built with 25% less lbs. of material than any gas engine of the same H. P. in the market and at a manufacturing cost per lb. not exceeding other types.

The Oechelheuser Gas Engine.

This engine is one of a number of important types of gas engines of large power; which have developed since the sudden demand caused by the utilization of "high-furnace" gases for gas engine driving. This engine has but one complete cycle per revolution. As illustrated in Fig. 29 it has one long horizontal water-cooled cylinder, containing two pistons, which between them perform the functions of admission and compression of the charging mixtures and the discharge of the products of combustion or exhaust gases. The engine has no valves or cam-shafts. It will be noted that the front piston is connected to the center of a three-throw crank and the rear piston to the two outer cranks. These cranks are 180° apart. The cross-head of the back piston is also attached to the piston-rod of a double-acting pump, which compresses the gas and air mixture on one side of its piston and air alone on the other side. As the two engine pistons approach in the cylinder, the mixture is compressed between them to a pressure of from 8 to 10 atmospheres and exploded electrically. The pistons are thus driven apart, each doing its work upon the main shaft. Before the completion of the full stroke the front piston uncovers the annular exhaust port, permitting the discharge of the exhaust gases. The rear piston at the end of its stroke uncovers first a port admitting air under slight pressure, to scour out the remaining products of combustion, and then a second port, through which the previously compressed explosive mixture from the pump is admitted. The exhaust port remains uncovered while the mixture pushes out the scavenging air, and then the pistons close all the ports on the return stroke. Compression then follows, and the cycle is repeated. It is claimed that none of the fresh charge

escapes through the exhaust, as the cylinder is so proportioned that even when running at maximum load the charge occupies but 70%. For slight variations in speed the governor controls the proportions of mixture of gas and air. For wider limits it regulates the quantity of charge through the mixing valve cock and the return slide valve. Part of the compressed charge passes into the suction pipe, and is then transferred to the other side of the pump, instead of to the motor cylinder, as usual. Admission and exhaust are effected in one stroke instead of two. The cylinder dimensions are smaller for the same power than in the four-cycle type of engine, as one stroke is obtained at each revolution, and as this is effected by two working pistons, acting on the same shaft, the power is said to be increased fourfold. The turning moment on the main



A.—Air. M.—Mixture air and gas. E.—Exhaust. G.—Gas. A.—Air.

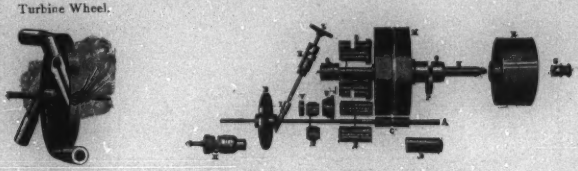
FIG. 29.—600 H. P. Oechelheuser Gas Engine.
(Engines of 1,000 and 1,200 H. P. under construction.)

shaft is produced by a couple, and the unbalanced forces transmitted to the bed-plate are much less than ordinary. Great regularity is obtained by the impulse at each revolution, and rapid expansion follows each explosion. The engine is, however, of considerable length, and the extra cost and complication of the three cranks, three connecting-rods and two cross-heads, rods, pump and pump-gear are to be taken into consideration. In the latest designs the pump is placed below the floor and under the engine, making a very compact arrangement. The Kraft Gas Gesellschaft, of Berlin, which is now manufacturing this engine at Aschersleben, is turning out a large number of these engines, up to 2,000 B. H. P., in the twin arrangement, for driving electrical machinery, fans, air-compressors, etc.

The Steam Turbine.

The very important work done in recent years upon the development of that oldest of steam engines, the steam turbine, bids fair to revolutionize steam engine practice, and although it is self-evident it does not possess the universal applicability of the ordinary steam engine, there is a very large field open for its application, and it is particularly well adapted to the needs of electrical engineers.

It is remarkably simple and compact, requires a minimum of attention and repairs, has no valves and no rubbing surfaces, except in the bearings, which in the forms employed show an insignificant wear, and the internal parts require no lubricant, consequently there is no danger of carrying grease into the boilers where they are fed by water condensation from surface condensers,



A.—Turbine Shaft. B.—Turbine Wheel. C.—Pinion. D.—Bearing of shaft end. F. G.—2 Part Bearings. H.—Thrust Bearing. I.—Feeding Nozzle. K. L.—Contro'ling valve. M.—Gear Wheel. N.—Motor Shaft. P.—Lubricating ring. Q.—Pulley. S.—Nut screw. T.—Exhanst valve.

Fig. 30.—Principal parts of the "de Laval" Steam Turbine.

and the absence of packing glands and internal rubbing surfaces permit of the use of steam of high degrees of superheat.

As there are no reciprocating parts and everything is so perfectly balanced the foundations are of but slight expense, it being only necessary to support so much dead weight. The turbine itself is comparatively light and economical in first cost and in operation, and will regulate within a very small percentage from no load to full load. In the ordinary steam engine live steam is admitted into the cylinder, which had been cooled but a moment before by its connection with the exhaust, the resulting condensation is not apparent in the steam turbine to any extent, owing to the gradual temperature changes and constant temperatures maintained at any given point.

In Fig. 30 is shown an illustration of the working parts of a de Laval turbine, such as has been extensively employed in

Europe and to some extent in this country, and in Fig. 31 is illustrated a standard 300 H. P. unit connected to two dynamos of corresponding output; this is the largest turbine of this type which has thus far been built. As indicative of the high class of workmanship and care necessary in constructing this type of high speed steam engine, I would call attention to the large gear wheels lettered M which I was informed at the Humboldt Works at Kalk, Germany, each took 14 days to complete. I made particular inquiries of various turbine manufacturers regarding the amount of wear of the blades, and was invariably told it was inappreciable where superheated steam was used. The de Laval Co. exhibited a 300 H. P. turbine wheel at the recent Paris

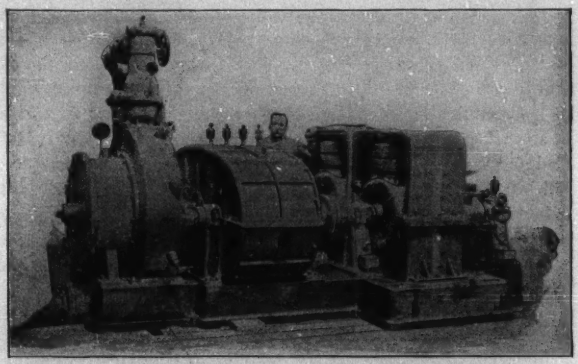


FIG. 31.—300 H. P. de Laval Turbine and Dynamos.

Exposition, in which the blades showed no apparent wear after having been in use for seven years. Prof. R. H. Thurston's recent test upon a de Laval turbine showed an increase in economy of one per cent. for each 3° Fahr. of superheat, and that with 37° of superheat the capacity of the turbine was doubled, due almost entirely, he claims, to the lessening of the skin friction.

In Fig. 30 is shown the turbine wheel B mounted upon the very slender shaft A, whose flexibility permits of its great deflection due to the forces set up by the turbine wheels running at such high speeds, and permits the wheel to revolve about its

axis of gravity; to the left of Fig. 30 is shown a wheel with its four nozzles, one of which is cut away to show the expansion of the steam as the opening diverges; the form of the blades is also indicated.

In Fig. 32 is shown an illustration of one of the two steam turbines ordered by the City of Elberfeld, Germany, from the firm of C. A. Parsons, to whom I am indebted for this original photograph. It is direct-connected to a 1,000 K. W. three-phase generator. A recent test was made by Messrs. Weber, Lindlay and Schroeter to determine steam consumption under different loads with the following results: Average pressure 11 atmospheres, the steam was superheated 14.3° cent, dynamo load 1,190 K. W. (overload), 955 K. W. (full load), 745 K. W. ($\frac{3}{4}$ load), 499 K. W. ($\frac{1}{2}$ load), 247 K. W. ($\frac{1}{4}$ load); the number of pounds of steam consumed per K. W. was respectively 19.3, 20.1, 22.2, 25.4, and 33.8. When running without the field magnets excited, the engine consumed 2,604 lbs. of steam per hour; when running with no load but field magnets excited, the turbine consumed 4,057 lbs. of steam per hour, the variation in speed from no load to full load and vice versa was 3.6 per cent. with non-inductive load, the fall in voltage from no load to full load was 1.02 per cent. with inductive load under similar conditions 11 per cent. This is the largest steam turbine constructed abroad up to the present, 1,500 H. P., but is exceeded by the Parsons 3,000 H. P. turbine installed by the Westinghouse Co. recently in Hartford, Conn.

The Sulphur Dioxide Gas, or "$S O_2$" Engine.

In 1899, Mr. R. Behrend, an engineer of Hamburg, Germany, and Dr. Zimmerman, of Ludwigshafen, patented a system which they had invented for utilizing the heat units contained in exhaust steam, and their tests showed gains as high as 56 per cent. additional power secured, without the expenditure of one pound additional fuel. The system developed by them and used upon an experimental engine plant, was not brought to perfection, by reason, among other things, of their difficulty in securing proper acid pumps. The improvements in ice-making machinery have now supplied the requisite pump, and a large amount of valuable data and experience. The results which they secured, however, were so promising that they brought them to the attention of Prof. E. Josse, of the Kgl. Technische Hochschule of Charlottenburg, Germany, an authority on subjects of this char-

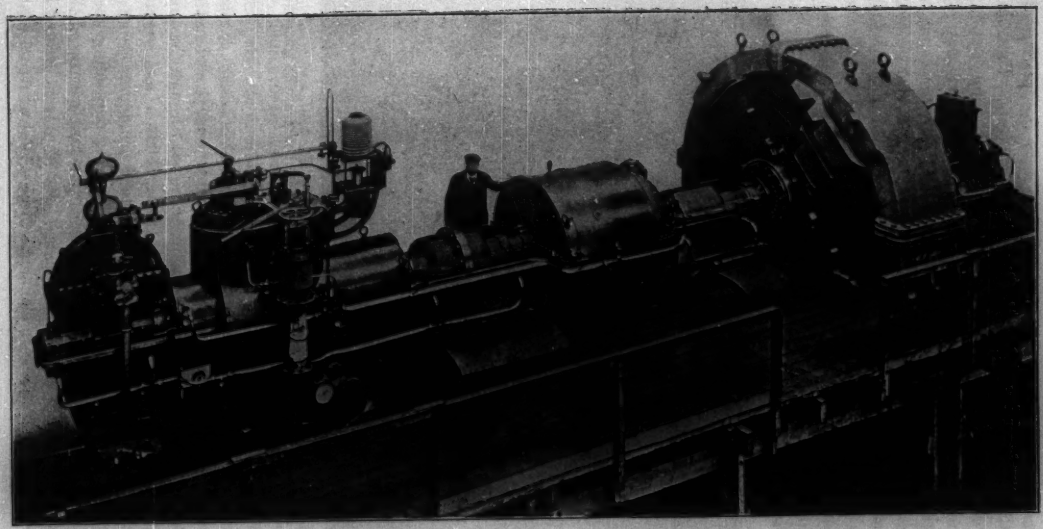


FIG. 32.—1000 K. W. Parsons Steam Turbine Outfit at Elberfeld, Germany. (1,500 to 2,000 H. P.)

acter, and they requested him to examine into the practicability of their ideas, and eventually to make further tests. Prof. Josse following up the work of Messrs. Behrend and Zimmerman, secured results of the greatest interest and importance, and the work which he now has in hand at Charlottenburg, is being carried forward in the interests of the three largest electrical concerns in Berlin, *i. e.*, Siemens and Halske, The Union Elektricitäts Gesellschaft, and the Allgemeine Elektricitäts Gesellschaft.

The system which has been developed is quite simple, and is briefly as follows:

As is well known in steam engine practice, after steam has

FIG. 33.—Sulphur Di-Oxide or "S O_2" Engine, in conjunction with compound Steam Engine. (The former is shown at the right.)

done its work in the cylinder or cylinders of a steam engine, there results a very considerable loss of heat energy; when the steam is discharged into the open air, or passed through the condenser. When exhausted in the open air, it has a temperature of about 212 deg. F., and in passing into a condenser it has a temperature of about 140 deg. to 160 deg. F., depending upon the amount of vacuum. The latent heat of steam given up in the changing from steam to hot water, has heretofore been wasted in the condensing water or in the air. Messrs. Behrend and Zim-

merman, desiring to utilize this waste caloric, employ it to create a new supply of power by vaporizing a liquid having a boiling point considerably lower than that of water, and after extensive experiments, adopted sulphurous acid (H_2 S O_3), a substance which is readily and economically obtained. Ammonia, nitrogen and benzol might also be thus employed, but the sulphurous acid, possesses the advantage that it can work in a cylinder without lubrication, which is not the case with ammonia. The pressures corresponding to the available temperatures are also favorable to the employment of this liquid. The working apparatus is shown in the appended illustration (Fig. 33), which represents the first engine tested at the Technische Hochschule. To the left is seen

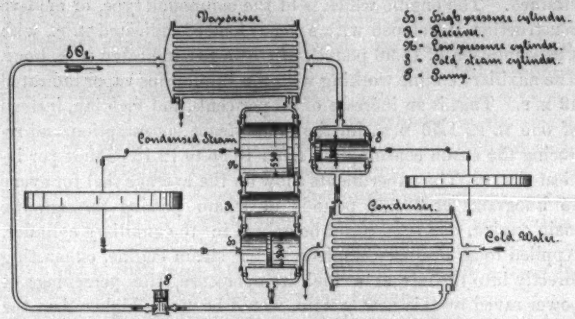


DIAGRAM SHOWING THE RELATIONS OF WORKING PARTS OF S. O_2 ENGINE.

FIG. 34.

the steam engine which has a pump for its load; behind it is the vaporizer; to the right, the S O_2 engine; and behind that the S O_2 condenser. This arrangement was designed by Prof. Josse. The principle and mechanical details are illustrated diagrammatically in Fig. 34. The dimensions given are in millimetres. The letters H and N represent the high and low pressures of an ordinary compound steam engine, with a stroke of 19.69 inches, and a speed of 41.5 revolutions per minute. From the low pressure cylinder end, exhaust steam passes into the surface condenser, or as it is termed, the "vaporizer." In this vaporizer or condenser, the sulphurous acid (H_2 S O_3) is utilized as the cooling medium instead of water. Possessing such a low boiling point, the heat of the exhaust steam liberates sulphur dioxide (S O_2) which, passing

into a cylinder of the auxiliary engine s, does its work as if it were an ordinary steam engine. This auxiliary cylinder has a diameter of 11.81 inches, a stroke of 19.69 inches, and a speed of 77 revolutions per minute. After being utilized in this cylinder, the sulphurous vapor, passes through the tubes in the surface condenser (shown in the diagram), around which tubes cold water is flowing, which condenses the sulphurous vapor again into sulphurous acid, which is pumped by the pump P back into the vaporizer, where it begins its cycle again—the same acid being used over and over again without loss. The machine is thus, in fact, a closed-heat engine. In a long series of tests made with the compound engine shown in Fig. 18, the following results were attained. The engine which is of the compound type, of modern construction, developed with a steady load 34 indicated H. P., with a consumption of 18.96 pounds of steam per indicated H. P. hour. The auxiliary engine working with the sulphurous vapor indicated 19 H. P. That is an increase of 56 per cent., and yielding, instead of one H. P., 1.56 H. P. for the same steam consumption, and reducing the steam consumption from 18.96 to 12.13 pounds per indicated H. P. The experiments show on the average that for every 15 kilograms or 33.169 pounds of steam passing through the main engine, one H. P. could be gained in the auxiliary cylinder. Applied to an ordinary single-cylinder steam engine, exhausting directly into the air at a high temperature, the percentage of power saved by this new system, would be much higher than the economy reached in these experiments, which are made with an improved compound engine. It is claimed from these experiments that given a fairly economical compound engine using 16.5 pounds of steam per indicated H. P. hour, that half an indicated H. P. could be produced in the auxiliary machine for each indicated H. P. developed in the main engine, assuming an average vacuum of 23.62 inches, corresponding to a temperature of 140° F. The saving of heat must be accomplished by using a liquid which can be vaporized at or below that temperature, and produce a high pressure. Assuming the upper and lower limits of temperature, within which the operation is confined, to be 140° and 67° F., the pressure of the sulphurous vapor would range from 10.05 to 2.35 atmospheres above open air pressure A working pressure as high as ordinary steam boiler pressure, is therefore readily obtained at a comparatively moderate temperature. The volume of sulphurous acid vapor, necessary to contain

the number of heat units, corresponding to the work to be performed, is much smaller than the volume of steam, which would be required for the same purpose. As the saving to be effected by the customary engine, depends directly upon the difference between the highest and lowest temperatures involved, the greater gain will therefore be made, either when the water in the surface condenser is as cold as possible, or when the heat of the exhaust steam from the engine is at a maximum, as is the case with a single-cylinder steam engine without condenser, which may be anywhere up to 212° F.

Sulphur dioxide gas or vapor is of a somewhat viscous character and lubricates the working surfaces of the machinery, and without producing corrosion. There is thus a considerable saving of lubricants. The expense of this improvement is practically covered in the cost of the auxiliary engine or extra cylinder attached to an ordinary engine, and the vaporizer, condenser, piping and pumps. It is claimed that a 2,000 H. P. central station engine would furnish power to drive an additional 1,000 H. P. $S O_2$ engine, which can be connected as an extra cylinder to the steam engine, or run independently, and thus increase about 50 per cent. the power developed without adding a pound to the quantity of fuel consumed. Prof. Josse states that in mining and iron works districts, there are a large number of engines, which are condensing and non-condensing, which consume more than 10 kg. of steam, and in such cases 2,000 H. P. would be gained in a plant of 3,000 H. P. by the use of the cold vapor engine.

A triple expansion steam engine, to which an $S O_2$ gas engine has been attached, is being used for supplying light and power to the technical high school in Charlottenburg. Exhaustive tests have been made, and are being made on this engine by Prof. Josse and his assistants. Through the courtesy of Prof. Josse and Mr. Louis Magee, Director of the Union Electric Co. of Berlin, I was enabled to secure the data here presented, and had the pleasure of seeing, recently, this engine running and undergoing test. Prof. Josse, to whom I am indebted for a beautiful photograph of this new engine which I regret to say I am unable to show you tonight on account of patents pending; informed me that even with the triple expansion the $S O_2$ engine gave an increase of H. P. of 35 per cent. with practically no increase in the operating expenses. I had hoped to present the latest results secured by this new engine, but they did not arrive

in time to embody them in this paper. Prof. Josse informed me that he believed it was inadvisable to go higher than double expansion, and that the preferable method of construction was to place the cylinder of the S O_2 engine in tandem with the steam cylinders. On my asking if there was any danger in moisture getting into the system, thus forming sulphuric acid, which would attack the surface of the cylinder, etc., he said this was impossible. This development in engineering practice is certainly a most interesting and promising one, and it is of interest to note that the Allgemeine Elektricitäts Gesellschaft is now installing an S O_2 engine in its Markgrafenstrasse station in Berlin. The system is not without its disadvantages, and even possible danger. Everyone knows the discomfort produced in a room where a common sulphur match is ignited, and in all types of engines there is always a possibility of a leak occurring. A comparatively small amount of sulphur dioxide gas produces a large amount of discomfort, and a large amount of it may incapacitate those working about the machinery, and if exposed thereto for a considerable length of time may even result in death. There are also the well-known corrosive effects produced. These are not cited with a view of disparaging this most interesting development, but would rather serve to indicate that for such a system to be most successful, the S O_2 engine should be operated as an independent engine, and so boxed in and ventilated as to reduce to a minimum the disadvantages resulting from possible leakage. The care of this engine is exceedingly simple, as no lubricant is necessary, and as for the existing steam engine absolutely nothing need be changed. In the methods of construction, very great care is taken to reduce the chances of leakage to a minimum. Great care is taken in the packing of the stuffing boxes, and in addition an extra stuffing box is placed on the cylinder, and connected to the condenser, so that although the pressure inside of the cylinder is 14 atmospheres, there is a pressure of but from one to one and a half atmospheres at the outer stuffing box. Prof. Josse says the engine can be made absolutely scentless, and that no difficulty need be experienced on this score. He also says the results of his tests far exceeded the original calculated and estimated results, and completely justify the practical application of the Behrend system for the improvement in steam engines.

A Trolley Omnibus.

In Fig. 35 is shown an illustration of the overhead double trolley circuit used to operate the electrical omnibus in the Vincennes Annex of the Paris Exhibition. The omnibus was

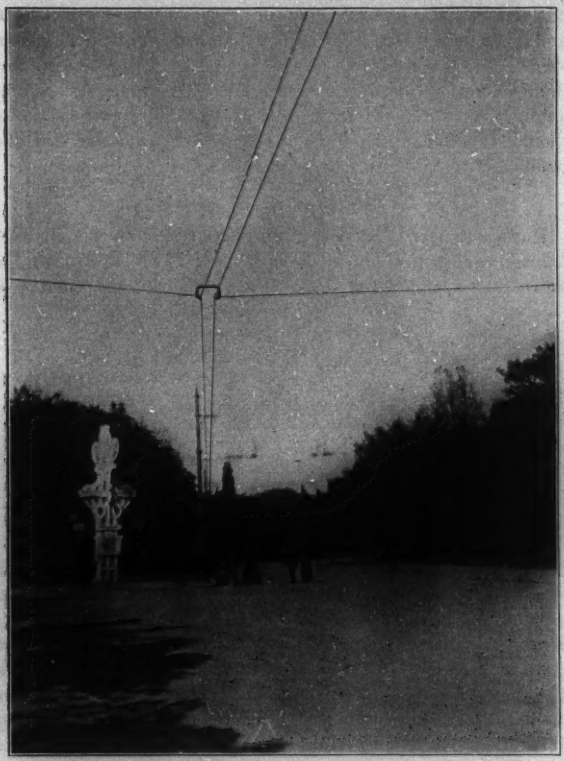


Fig. 35.—Double Trolley Line for Electric Omnibus at Vincennes, Paris.

flexibly connected with a traveling trolley, which was driven by an electric motor and which traveled along on the two overhead wires. The current supplied to the motor on the omnibus was a direct current, and connections were made therewith, so as to

supply the three-phase current to the motor driving the trolley-carrier. On starting the omnibus the current was first thrown on to this overhead motor, so that it started along on the trolley wires and remained continuously in advance of the omnibus as it passed along the road. The trolley wires were suspended first on one side of the road, then on the other and at times in the center, and the omnibus itself wended its way in and out of the numerous vehicles on the road with perfect facility. It would seem that there are various places where such a trolley automobile could be applied, but it does not seem essential that the over-head motor should be driven by a three-phase current while the line and omnibus motor itself are supplied with a direct current.

The Electric Plough.

During my stay in Berlin, through the courtesy of Director Louis Magee of the Union Electric Co., I was shown an improved form of electric plough at work in the suburbs of

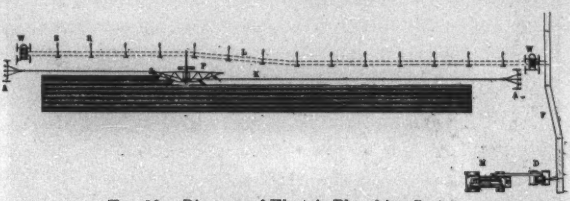


Fig. 36.—Diagram of Electric Ploughing System.

Berlin. The illustrations in Figs. 36 and 37 will serve to indicate the system employed. Direct current at 500 volts was supplied from the neighboring station of the Berlin Electricity Works, and the plough itself was equipped with three ploughshares at each end, and was estimated to do the work of 15 horses. The illustrations serve to indicate quite clearly how in this system the line wire was connected to the traveling reels and to the trolley lines, and shows how this line is moved sideways across the field as the plough progresses. The feeding chain and anchors are shown, and the method of tipping up the plough body in starting a new furrow on the return trip. I found it necessary to walk quite rapidly to keep up with the plough, which was simultaneously cutting three deep furrows in soft loam in a very impressive manner.

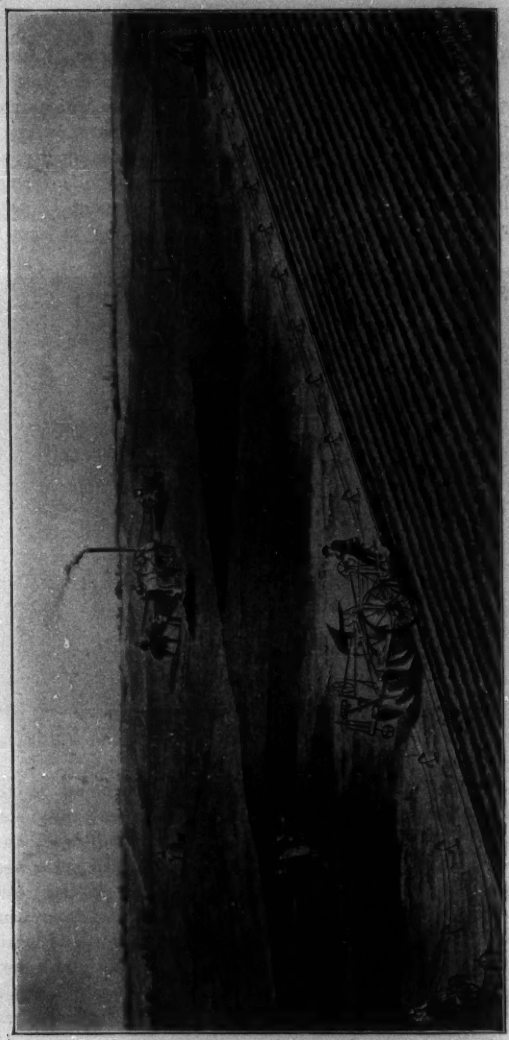


FIG. 37.—The Electric Ploughing System in Operation.

GANZ & CO.'S HIGH-TENSION THREE-PHASE R. R. SYSTEM.

Through the courtesy of Director Otto F. Blathy, of Messrs. Ganz & Co., of Budapest, I was enabled to examine into the company's high-tension three-phase railroad system, which is now being installed upon the Lecco, Sondrio & Chiavenna line in North Italy, and which system was at the time of my visit being run experimentally upon a circular track a mile in length at Alte-Ofen Island, in the Danube, near Budapest, Hungary, illustrations of which are shown in Figs. 38, 39 and 40.

FIG. 38.—Ganz & Co.'s Experimental 3-Phase R. R. at Alte-Ofen, Budapest.

The length of the Italian electric road, which up to the present has been operated by steam, is 66 miles and the maximum grade 22%. It is safe to say that this road, by reason of its great length, problems in freight and passenger haulage, high potential employed, and its special electrical and mechanical features, represents the most interesting electrical railway installation now under construction, and it will be followed with the greatest interest. The motive power now being arranged for represents about 7,400 H. P., with facilities for increasing when necessary. The power will be derived

from a waterfall near Morbegno, 9½ miles from Calico and 15½ miles from Sondrio. Four 2,000 H. P. Shuckert three-phase dynamos generating 20,000 volts at 15 cycles are direct-connected to four turbines, which are supplied from a raceway between two and three miles long, delivering 35 cubic meters of water per second and having a fall of 30 metres. The three-phase current of 20,000 volts will be supplied direct to the line, and the 12 sub-stations will transform it to 3,000 volts and supply 12 independent sections of the railway line, each of which is equipped with fuses. Two over-head trolley wires

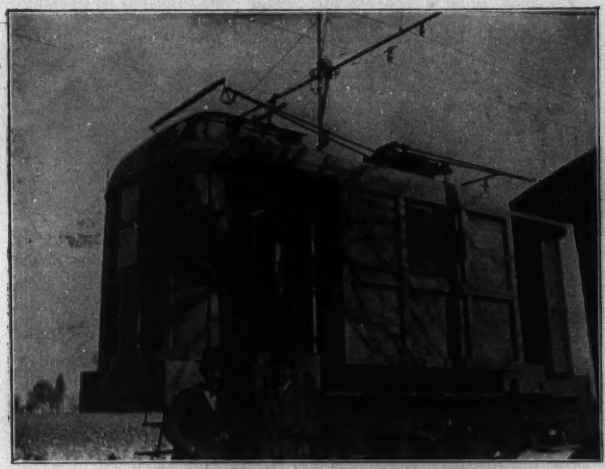


FIG. 39.—Ganz & Co.'s Electric Locomotive at Alte-Ofen.

8 mm. in diameter represent two of the phases and the track the third. The line insulators are of porcelain, having five petticoats decreasing in size from top to bottom. The line wire, which is of copper, is 7 mm. in diameter. The sections of road are operated upon an ingenious block system; when the stop-signal is set, the line circuit is opened and simultaneously the powerful brakes on the train are set. Passenger and freight traffic are operated independently. The freight locomotives will be of 700 H. P., employing four motors, and capable

of hauling 250 tons at a speed of 19 miles an hour up a 10% grade. The passenger locomotives are also equipped with four motors, each weighing about 3½ tons and representing 300 H. P. The schedule speed is about 37½ miles an hour on the level and about half that on grades. The 3,000-volt current is taken from the trolley lines by two copper rollers 16″ long and having a diameter of 3¼″. These rollers, which are mounted in the same axial line, revolve upon steel ball bearings (through which no current, however, passes) and are separated by 5″ of hard wood saturated in paraffine under pressure. On the left and right

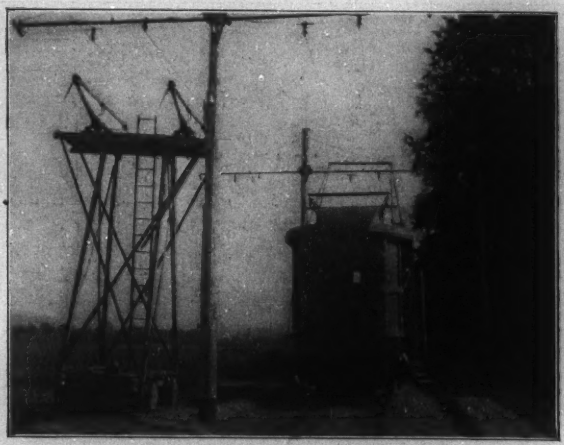


FIG. 40.—Showing details of Alte-Ofen Line, Budapest.

sides of this pair of rollers are copper cones about 8″ long, rigidly connected to the trolley-support. The base of the trolley is mounted on a long horizontal hinge on the top of the car and connected to a piston of an air-cylinder, so that the trolley can be raised and lowered by air-pressure. Each of the "primary" or high-tension motors has its trolley with double rollers. Collecting-brushes running on graphite collars take the current from the two rollers, being held against them by spiral springs. The current is then led by highly-insulated wires, protected by grounded metallic tubing, to the motors.

Each car is mounted on two four-wheel trucks, one of which is illustrated in Fig. 41, and is equipped with two "primary" and two "secondary" induction motors, or four in all, each of 150 H. P. Each rotor weighs about 1½ tons. The air-gap is between 4 and 5 mm. The 3,000-volt current passes directly to the stationary windings of the "primary" motors. In starting up the train or in climbing a grade the motors are connected in "cascade"—that is, the windings of the "primary" rotors, which are designed for 300 volts, are connected to the stationary windings of the "secondary" motors, while their rotors are connected to the fluid resistances; this gives a speed of about 18½ miles per hour. When speed is attained the controller-handle

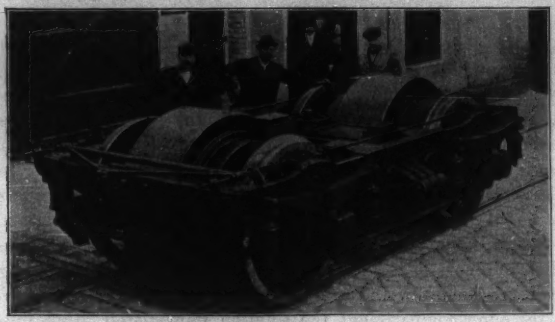


FIG. 41.—Ganz & Co.'s Electric Locomotive Truck, with Two Three-phaze Motors, for Italian Railroad.

(which has only two positions, "half-speed" and "full-speed") is thrown to its second point, which throws the stationary fields of the "primary" motors on the line, and their rotors on the fluid resistances which are slowly cut out of circuit, the secondary motors meantime being thrown out of circuit. This arrangement gives a speed of 37½ miles per hour. The wires in both field and rotor windings are invisible as they pass longitudinally through insulated tubes in the iron, and at the ends of the windings are insulated by mica and protected by plates or caps bolted on. The controllers at each end of the car are connected mechanically, and the high-tension switches are connected electrically. A small transformer on the locomotive connected

to the line delivers current at 100 volts to a three-phase motor for compressing air for use on the air-brakes, operating the high tension switch, raising and lowering the fluid in the resistance boxes (which is simpler than raising the plates), and for raising and lowering the trolley. The same transformer supplies current for lighting the train; Cruto three-phase incandescent lamps are employed, the periodicity being but 15 per second, the fluctuations were too noticeable in the ordinary lamps, so the Cruto 3-filament lamp was employed and showed no fluctuation.

The three-phase liquid rheostat is a feature of considerable interest. It consists of an iron box having three wings to it. From the top of the box depend three separate cylinders. Supported inside of each cylinder are two sets of iron plates. They are of varying length, and are rounded at the lower extremity. The alternate plates are connected in pairs, the current entering by one pair and leaving by the other, the sets being attached to the three phases of the low-tension rotor circuits, which have a potential of 300 volts. The lower portion of the outer case contains a solution of sodium carbonate. The upper portion of this outer case is supplied with compressed air, which, according to the rate with which it is allowed to pass into the outer chamber, causes the liquid to rise in the three cylinders. The liquid as it rises, comes in contact with the various iron plates, one after the other, and more or less resistance is thus cut of circuit, depending upon the height of the solution. By releasing the air pressure in the outer compartment, the solution immediately drops into the lower part of the case, and the plates are then entirely separated from each other. The entire height through which the solution passes is less than 12 inches. This resistance box, which is the result of a large amount of experimentation, enables the motor-driving torque to be kept constant during acceleration. The air exhaust valve is a lift type of valve, normally kept open by a spiral spring. The valve for operating the rheostat is compound, having several ways through it. On being operated, the latter first opens a clear way for the compressed air to a cylinder, and to the top of a piston which compresses the spiral spring above referred to, and closes the exhaust valve. The air is next admitted slowly through a small throttling aperture, which admits the air at low pressure, to the outside of the resistance box casing. When half-speed has been attained, the motion of the controller lever when thrown to full speed, causes

the air cock to close the throttling aperture, and open another, thus relieving the air above the upper surface of the exhaust valve piston, permitting the compression spring on this valve to instantly open it, thus throwing in again instantly the whole resistance. These operations are repeated in securing acceleration from half to full speed, and in securing retardation from full to half speed, at which time the motors are in "cascade," as described.

The motors are direct-connected to the axle; that is, there is no gearing; the rotor axle is hollow, with an internal diameter of 8″ and is lined with brass, permitting the car axle, which has a diameter of 4″, to pass through it. The circuits to the three collector-rings pass through grooves in the rotor shaft. The rotor shaft and the car wheels are flexibly connected, and thus jarring and vibration are prevented. The rotor has at one end the three collector-rings, upon which rest the three carbon block brushes. At the other end of the rotor is a driving-flange, which is connected to the driving-wheel on that side through two links, one of which acts by thrust and the other by tension, the two stresses being of equal magnitude.

In the experimental plant at Alte-Ofen, Budapest, a potential of 3,000 volts was supplied from a neighboring plant and the locomotive shown in Figs. 39 and 40, had but two motors upon it. The photos and lantern slides will serve to indicate the character of the car, track, trolley lines, methods of insulation, etc. I am indebted to Dr. Otto F. Blathy and Mr. Windisch Antal of Messrs. Ganz & Co., and to Mr. Francis Jehl, for assistance in preparing this data and for my trips over the road.

Siemens & Halske High Tension Three-Phase R. R.

The firms of Siemens & Halske, Allgemeine Elektricitats Gesellschaft, and Borsig & Co., of Berlin, have formed an organization for the study of problems connected with the operation of electric railways under steam conditions. The work I shall refer to here has been prosecuted by the first mentioned firm, which has for a considerable period given this subject attention. I am indebted to the company's engineers, particularly to Mr. Walter Reichel, the Chief Engineer of Messrs. Siemens & Halske, for the data here presented. Mr. Michael Dolivo-Dobrowolsky, Chief Engineer of the Allgemeine Co., informed

the author his company is also constructing a locomotive for experimental test, and Borsig & Co., the well-known engine builders, are co-operating with the other concerns in this important undertaking. Messrs. Siemens & Halske had made some interesting experiments with three-phase current in the year 1892 at the Werner Works, Charlottenburg, upon a track 360 metres long, and in the year 1897 decided to build a special experimental line for testing an electrical equipment

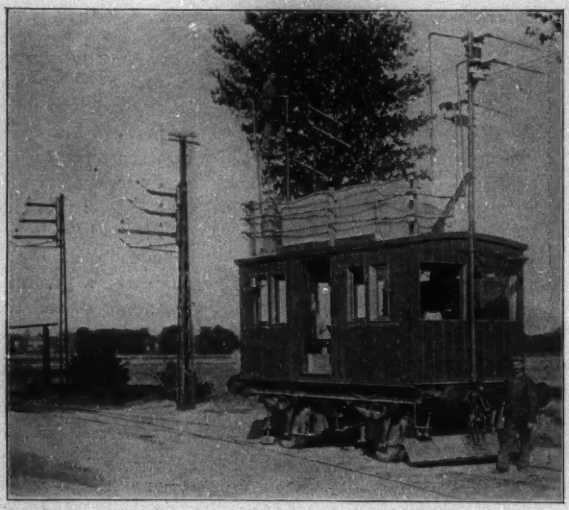


FIG. 42.—Original Arrangement of S. & H. Three-Phase R. R. near Berlin.

employing rotary current motors, and an E. M. F. of 10,000 volts, and for testing various types of trolleys, circuit safeguards, crossing constructions, etc. The line was built from Grosse Lichterfelde to Zeblendorf over the Teltow road, and was undertaken in the spring of 1898, the track being laid for 1.8 km., standard gauge, with the power station at about the center of the line. The more recent tests referred to here, were conducted in the spring and fall of 1899, and the final tests in the spring of 1900.

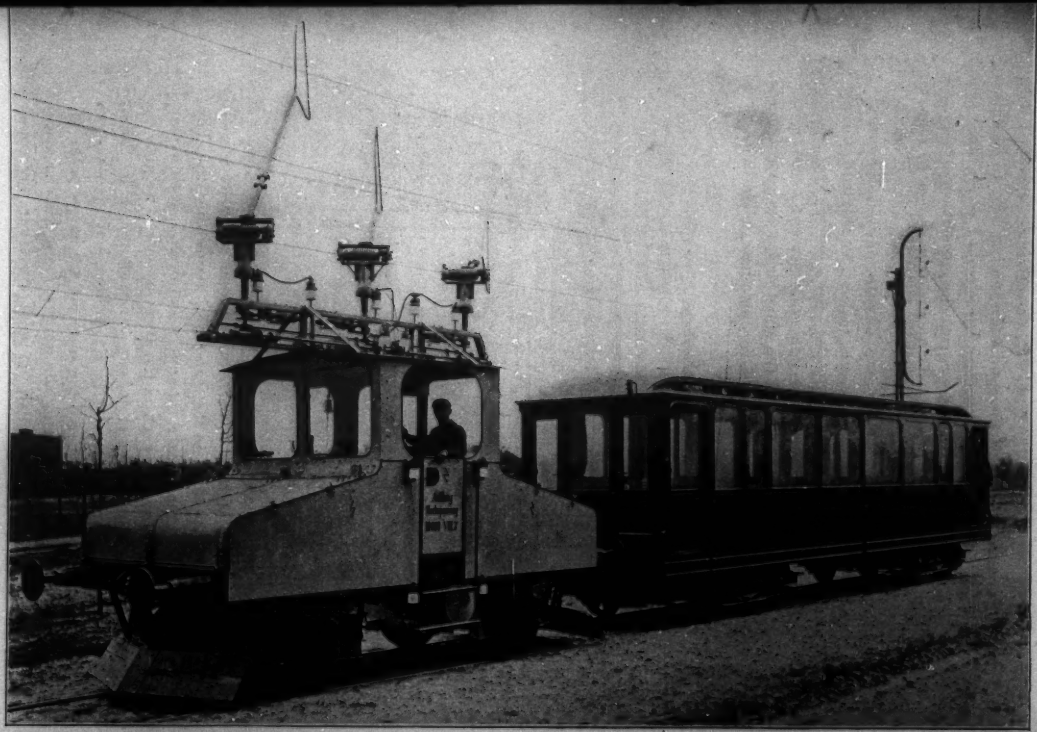


FIG. 43.—Latest Equipment Siemens & Halske Experimental Three-phase R. R. near Berlin, Germany.

In Fig. 42 is shown the trolley line as originally arranged with the protective net below the conductors, and in Fig. 43 is shown the improved method of supporting the trolley wires and protective net. In the first arrangement the current was taken off by sliding contacts on the top of the wires, as shown in Figs. 36 and 38, and subsequently by side rubbing or sliding contacts. It was feared that at the high rates of speed desired, the ordinary forms of trolley wheels, loops and rollers, would tend to leave the wire. All three of the trolley wires, which are of hard drawn copper wire 8 mm. diameter, were placed at the side of the road, in order to get rid of the effect produced upon the telephone system by using the track for one-phase. The wires were

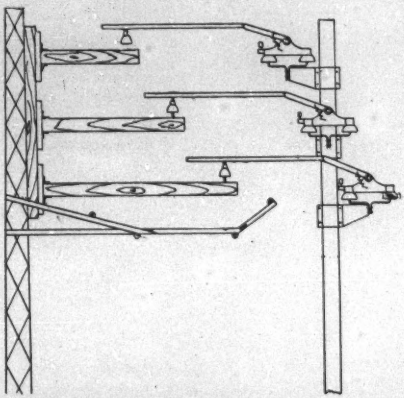


Fig. 44.—Original Arrangement of Trolleys.

held by porcelain bell insulators, tested for $\frac{1}{2}$ hour under water at 1,500 volts, and lay at an inclined plane, and were screwed to wooden arms pivoted to the iron poles, permitting the wires to be strung and maintained separately and evenly, both winter and summer. Tension is kept on the wires by heavy weights placed inside the lattice poles at definite intervals, which act through a loose pulley and a block with six pulleys, and give a strain of 1,500 kg. on the wires. All the supports are lattice poles 40 metres apart, the ones carrying the weights being heavier and set in cement. As a precaution all the poles are separately connected

to the rails by a copper wire 8 mm. diameter. Fig. 44 indicates the method of taking the current from the trolley wire. The trolleys consisted of strong aluminium pieces, pivoted about a horizontal axis, and fastened to an iron pipe, the contact parts swinging in a perpendicular plane to the working wires, against which they are held by a spring. In the system later employed, all three conductors lie in a vertical plane one metre apart. Curved iron supports are attached to the lattice poles. At the ends of these supports are tension devices, and the insulator supports are fastened at a slight angle. The three-part porcelain bell insulators are fastened to the support by means of a hempen rope; there is double insulation top and bottom. Sections of the conductor can move sideways, and yield to pressure as in the case of the ordinary under-running trolley. Metallic supports for the trolley wires tightly embrace the neck of the porcelain insulators, by means of pressure screws and spring rings. In Figs. 43 and 45 three bow trolleys are shown on top of the locomotive. Each is pivoted upon perpendicular axles, all of the same height, and which are insulated by strong hard rubber insulators. The loops or bows are of different lengths and inclinations. They also pivot horizontally to pass below crossings, etc., and are controlled simultaneously by a worm gear, operated from inside the cab. The working conductors and trolleys were tested with a current as high as 30,000 volts. Power is supplied from the sub-station of the Grosse-Lichterfelde Railway, which has a storage battery and direct-current motors for driving a rotary current dynamo. The latter is 12-pole, giving normally 700 v. and 50 periods, and 120 to 250 amperes at 500 revolutions per minute. This machine can be completely altered so that potentials from 385 to 4000 volts can be developed. There is also a rotary current transformer, with a transforming relation of $\frac{750}{10{,}000}$ v. with $\frac{157}{11.5}$ A. normal. With this plan it was possible to secure 750 v. directly, 2,000 v. directly, and 10,000 v. by transformation. The transformer dynamo frame and instrument cases were all grounded as a precaution. As first operated, the transformer stepping down from 10,000 to 750 volts was drawn along on a separate attached car with trolleys, in order to better observe the sliding contacts, and to be free from the high tension at the motor, which has no iron casing. There was also only enough room in the locomotive for the large resistances and other apparatus.

Later an iron top casing was put on the locomotive, in which the transformer was placed—the equipment having the appearance as shown in Fig. 45. The metal parts of the locomotive are grounded to protect against the difference in potential. The

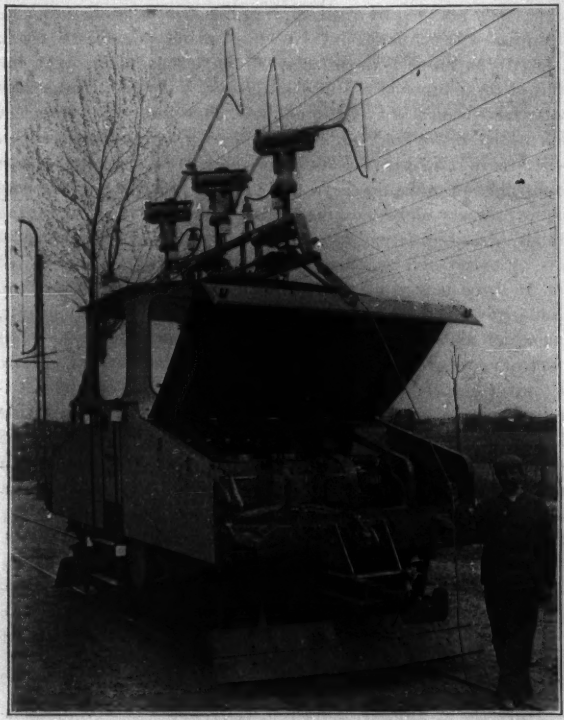


FIG. 45.—Siemens & Halske Three-phase Locomotive with Cover Raised, Showing Transformers, etc.

weight of the locomotive complete, was 16,000 kg. It is equipped with two rotary current motors, one on each of the two axles, and operating at 650 to 850 volts and 30 H. P. normal. The current is taken direct to the stationary windings. The rotor is

provided with slip rings and ventilation. The air gap is 1.5 mm. Tested, these motors show an efficiency of 88.5 per cent., and the highest type is of 120 H. P. with 650 V., which is increased to 200 H. P. at 850 volts. The motors are flexibly suspended, similar to the street railway motors, and can turn upon the axles. Two pair of gear wheels serve to change the speed, with a gear of 1 : 4.65 for a speed of 40 km and 1 : 3.15 for a speed of 60 km. For the operations of 750, 2,000 and 10,000 volts, the same motors, frames, and rotary parts were used—only the stationary parts being exchanged for the direct operation with 2,000 volts.

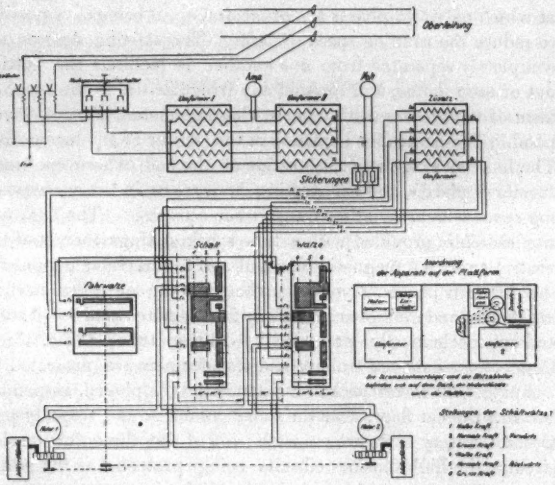


FIG. 46.—Diagram of Circuits.

Referring to the circuit diagram, Fig. 46 a controller constructed for 750 volts is employed for the switching in and out, and for the starting of the motors. The same has in its interior a reverser drum for changing the running direction, and a controller drum for switching the stationary windings of the motor in and out. The controller drum is mechanically connected by a chain gear with the starting devices for the rotating parts of the motors. When running with 750 volts, the controller is directly connected

with the trolleys. When running with 10,000 volts, it is however connected through the transformer, from 10,000 volts to 750 volts, and a switch for 10,000 volts. Running with 2,000 volts the supply conductors to the primary parts of the motor can be cut off from the controller, and the car operated by two auxiliary switches, and without the use of the transformer. The reverser drum of the controller is so arranged that when employing an additional transformer (for instance with 10,000 volts) different currents can be taken off, thus obtaining the higher torque when starting through a higher E. M. F. (850 volts) than during the normal running (650 volts). The reverser drum finally has steps at which only two phases are connected up, it being thus possible to reduce the running speed by half. The starting devices are completely separated from one another to facilitate the cutting out of each motor, and to avoid any irregularities in the synchronism of the motors, with wheels whose diameters did not correspond. The controller is placed in the center of the locomotive. The high tension switch is outside at the end where one transformer is placed, and the starting devices are in the corresponding space which the other transformer occupies. The high tension switch is provided with a tube spark extinguisher, and the controller with a magnetic blow-out and a successive cut-out for the different phases. Connections between the controller, starting resistances and motors are carefully insulated to stand 4,000 volts, and are mechanically protected by rubber tubes, 6 mm. thick. Connections between trolleys and transformers are protected by one pipe. Ordinary packed resistances are employed, suspended beneath the car floor, near the starting devices, and properly protected. Safety fuses are on each side of the three low tension circuits, the high tension circuits being protected at the power house. Siemens horned (non-inductive) lightning arresters are used on the locomotive for each phase. Hand and air brakes are employed, and the usual volt and ampere meters. A locomotive with a load of 30 tons was run up to a speed of 60 km in 60 seconds time, with 700 v and 190 A. The locomotive alone, attained the same speed in 30 seconds. When run with a load of 30 tons at 60 km per hour, the motor consumed 70 A. at 700 volts. As is known, the starting torque varies with the square of the voltage; therefore, by increasing from 670 to 950 volts, the starting torque can be increased to double that at the normal tension. This can easily be obtained when employing transformers

(in the operation with 10,000 v) by the addition of coil sections. The speed may be regulated by wheel resistances in the secondary, by opening a secondary circuit, or by "cascade" coupling. The first method causes a loss of current; in the second the motor has a somewhat lesser maximum torque—lesser efficiency, and a smaller output corresponding to half the number of revolutions; it is, however, preferable to resistance regulation. The same may be said of the "cascade" coupling, in which the torque is reduced to half of the output = to ¼. A braking action of the motors was obtained by decreasing the number of alternations of the dynamo through an increase of the field of the driving motors; likewise current was sent back to the accumulator battery, when going down hill.

The "Jungfrau" Three-Phase Railway.

The Jungfrau Railroad which has been under construction since 1897, and which, it is estimated, cannot be completed before 1908 to 1910, has attracted the attention of engineers the world over. It employs three-phase current of 7,000 volts, supplied by generators, operated by water power. Portions of the current are transformed to 120 volts, for the lighting of Lauterbrunnen and Wegern, and at stations, and for tunnel boring. The current for operating the locomotive is transformed to 500 volts. Two overhead contact wires are employed, the rails being used as the third conductor; the trolley wires are 16″ apart, and have double insulation between each other and between each wire and ground. These insulators come from America and were supplied by A. & J. M. Anderson of Boston, Mass. The supports are about 100 feet apart. Double trolleys with both slide and wheel contact makers are employed, as shown in Figs. 41 and 42.

The overhead conductors are bare, and supported on triple-petticoat porcelain insulators, mounted on wooden posts. A ten per cent. loss is allowed on the conductors. Lightning protectors are of the Siemens & Halske horned type, at each end of the circuits, and on every pole is a pointed wire connected to the earth.

The electrical generators are supplied by the Oerlikon Company, which also supplied the transformers and appurtenances, at present consisting of two units of 500 H. P., and one of 800 H. P., direct coupled to Gerard turbines, made by Reiter & Co. of Zurich, and having horizontal shafts with two wheels

running at 380 revolutions. These generators are of the inductor type with stationary windings, and generate a three-phase current of 38 cycles and 7,000 volts, running at a speed of 380 revolutions per minute. They are connected to the turbines by flexible insulating couplings and are mounted upon porcelain insulators. Two exciters of 25 H. P. each at 600 revolutions, supply a direct current of 120 volts for exciting the fields. These exciters are shunt wound, and direct coupled to separate turbines. Each exciter is capable of exciting all four generators

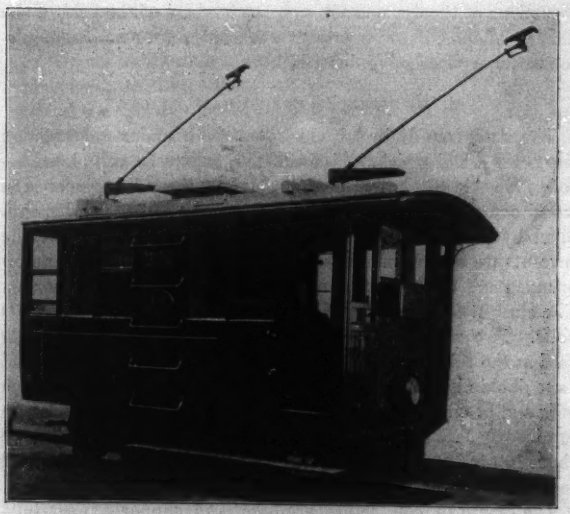


FIG. 47.—"Jungfrau" 3-Phase R. R. Locomotive.

which will constitute the plant. All of the turbines are automatically regulated. The present station at Lauterbrunnen will supply 2,000 H. P. from the "Weisse" Lutschine, and that at Grindelwald will supply, when completed, 3,000 H. P. This supply comes from the "Schwartze" Lutschine which gives 9,000 available H. P. The total length of the transmission line from the Lauter-brunnen Station to the top of the mountain is about twenty miles. At ten per cent. drop, the allowance would be about

700 volts. The conductors are about 5/16″ diameter, and when the road is completed, there will be twelve substations along the entire line, about one and a half miles apart,—the highest being about 13,000 feet above the sea. There will be about seven miles of tunnel on this road—alone costing $1,000,000. The trolley wires in the tunnel are supported by iron hooks projecting from the rocks. Owing to the nature of the rocks it has not

Fig. 48.—"Jungfrau" 3-Phase R. R. Locomotive.

been necessary to face the tunnel with stonework. About fifty H. P. is used for running eight three-phase current motors, for driving ventilators, pumps, etc. in the tunnel work, and continuous current is also used for operating boring machines on the electrical percussion solenoid principle. The transformers consist of three vertical iron cores, on which the primary and

secondary coils are placed co-axially over one another. They are of 200 K. W., and give a secondary voltage of 500 volts.

In Figs. 47, 48 and 49 are shown types of the electric locomotives employed on the Jungfrau road. There are five locomotives. Two of them were made by Brown, Boveri & Co. of Baden, with an individual weight of 13 tons, and each locomotive has two motors with a maximum output of 200 H. P. and a speed of 760 revolutions per minute; the other three locomotives were made by the Oerlikon Company of Zurich, and are each of 19 tons weight, each being equipped with two 220 H. P. induction motors with a normal speed of 500 revolutions per minute. The locomotives are designed to make an ascending speed of five miles

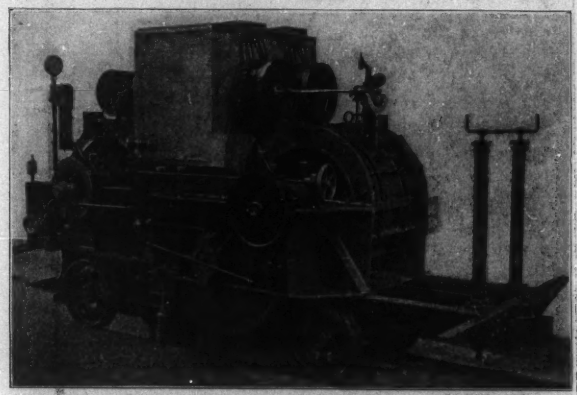


FIG. 49.—Showing "Jungfrau" locomotive construction.

an hour and draw two cars seating eighty persons. These motors are connected by a double reduction gearing. A sprocket wheel having teeth 4″ pitch and $2\frac{5}{8}$″ broad, of aluminium bronze, engages a continuous "Strub" rack laid between the rails of the road. This rack is put down in ten feet sections, its height above the ties is about 7″, the pitch 4″, the breadth of the teeth is $2\frac{1}{2}$″ and the tooth depth $2\frac{1}{2}$″. The rails are of steel, 42 lbs. to the yard and 32 feet in length, and the gauge 3.28 ft. In the open they are laid upon wood ties and in the tunnel upon cast iron ties. A controller cuts resistance in and out of the rotor circuits, which

resistances are kept cool by air forced through them by a ventilating fan driven by a three-phase induction motor. In the first locomotives built by Brown, Boveri & Co., one resistance was used for two motors. This had the disadvantage of producing "hunting" when the two motors were thrown in parallel, and caused a jarring action at times. In the later Oerlikon types each motor has a separate resistance, which was used not only for starting, but also for absorbing current when the locomotive was descending, at which time the motors are left in circuit to secure the automatic braking action, and giving the generators a nearly constant load. These descending locomotives may at times supply current to the line, thus assisting the ascending cars. The locomotives will start themselves on a grade of 25 per cent. By mounting one end of a car on an extension of the locomotive frame the traction has been favorably increased, and to secure the greatest benefit of this weight the cars are put in front of the locomotive in going up hill, and behind it in descending.

It was customary at one time before descending, to signal the Lauter-brunnen power house, and resistance was put in circuit, but later the locomotives were equipped with a resistance qualified to absorb the whole current generated by the motors in descending. This saves wear and tear on brakes and turbines, generators, etc., and wastes no extra power as the water must pass the power house at any rate.

The cars are equipped with hand, automatic and electric brakes, as required by Swiss Mountain regulations. One of these locomotives is shown in Fig. 49. Messrs. West-Kunz and Thorman in their report to the Jungfrau Railway Commission upon the relative advantages of employing three-phase transmission with rotary converter sub-stations and continuous current motors on the locomotives, as compared with the employment of three-phase current throughout, advised the employment of the latter for the following reasons:

1st, because of the greater simplicity of the regulating arrangements of the motors.

2nd, because of the automatic braking action in descending grades.

3rd, because of the expense and difficulty in maintaining sub-stations, employing rotating machinery, and assistants to relieve each other periodically.

4th, because after very careful estimates had been prepared

from manufacturers' actual prices, it was found that the first cost of the rotary converter method would be over 50 per cent. greater than that of a system in which three-phase currents only were employed.

Fig. 50 is a diagram of the wiring of the generating station and locomotives. When the road is completed it is proposed to transport the passengers 300 feet higher, to the summit, by means of an electric elevator, (which I show in accompanying lantern slides), upon which will be mounted a three-phase motor, carrying two pinions, working in racks on the side of the shaft.

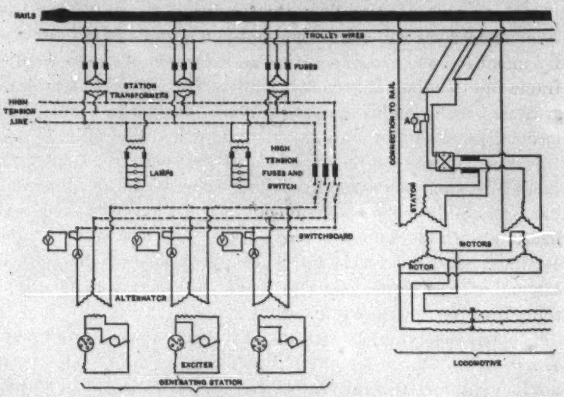


FIG. 50.—Diagram of Generating Station and Locomotive Circuits Jungfrau R. R.

The Jungfrau is 13,667 feet above the sea level and 11,808 ft. above Interlaken.

The electric road is now open from Kleine Scheidegg—which is 4,270 feet above Interlaken—to Rothstock, and although financial difficulties have recently delayed the work, it is expected that Eismere will be reached in 1903 and, as before stated, the road entirely completed between 1908 and 1910.

When completed the round-trip fare will be 35 francs or about $7.

The entire cost of the road when completed is estimated at $2,000,000.

The distance from the commencement of the electric line to the tunnel is about six miles.

At each of the transformer sub-stations, which are in the main cut out of the solid rock, space is given for three transformers, for the necessary switches, instruments, etc., all of which are carefully insulated by glass or porcelain.

There are special sub-stations at Kleine Scheidegg and at Eigerglacier, containing an additional transformer of 40 K. W. and a rotary transformer of the same capacity, and also a set of storage batteries. These can be used in case of breakdown or stoppage, and for lighting the buildings, supplying the tunnel work, etc.

A difficult problem has been to satisfactorily reduce the speed of locomotives going down hill, which always exceeded the ascending speed by reason of the fact that three-phase generators run faster as generators than as motors. The Oerlikon Company has neatly solved the difficulty by attaching a small direct-current dynamo to the motor-shaft and supplying a direct current to the stator windings of each motor; a resistance placed in circuit permits the regulating of the direct current and secures a speed about half that of ascending. When the locomotive starts to descend, the over-head trolleys are lowered, and the three-phase current generated by the rotor is absorbed by the motor-starting resistance, which is much less than formerly. This brake arrangement has displaced the magnetic brake, which is only in circuit when going uphill.

The two rack pinions are 28″ at the pitch drain, the number of teeth 22 and pitch 4″. At either side of the rack pinions, are grooved wheels 4″ broad, each with four V-shaped grooves, into which fit iron clamps at both sides of the horizontal drain. Thus by turning either brake-handle, the brake acts at eight points simultaneously at both ends of these axles on the spur-wheels of the second gear; the reduction is 2 to 1 and the pitch 1″; the reduction by the first gear is 5.6 to 1 and pitch slightly less than 1″.

It is said that before 1851 but five successful attempts were made to ascend the Jungfrau, and while many plans have been suggested for carrying the public to the summit, it remained for the celebrated engineer, Mr. Guyer Zeller, to bring forward the first practicable plan. This was in 1893, and in the following year he was granted the necessary franchise to carry out the

work, which he prosecuted with great energy and skill until his death in the year 1899.

The author has visited other important Swiss three-phase electric railways, but deems it inadvisable, by reason of the length of his paper, to present at this time data on others than that most interesting and typical road the "Jungfrau." He will, however, show some interesting lantern slides of the Stansstadt-Engelberg and Burgdorf-Thun three-phase Swiss mountain electric railways.

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Contents of Vol. XVI, 1899.

THE EDUCATION OF ELECTRICAL APPRENTICES AND JOURNEYMEN. By Arthur A. Hamerschlag. ELECTRICITY ON BOARD SHIP. By S. Dana Greene. No. 1, January, 1899. STORAGE BATTERIES AND RAILWAY POWER STATIONS. (Illustrated.) By R. McA. Lloyd. No. 2, February, 1899. PROPAGATION OF LONG ELECTRICAL WAVES. (Illustrated.) By M. I. Pupin. No. 3, March, 1899. THE LIMITATIONS OF POWER SUBDIVISION BY ELECTRIC MOTORS IN MANUFACTURING ESTABLISHMENTS. (A Discussion.) No. 4, April, 1899. THE MULTIPLE UNIT SYSTEM OF ELECTRIC RAILWAYS. (Illustrated.) By Frank J. Sprague. No. 5, May, 1899. REPORT OF THE COMMITTEE ON STANDARDIZATION. SYMBOLIC REPRESENTATION OF GENERAL ALTERNATING WAVES AND OF DOUBLE FREQUENCY VECTOR PRODUCTS. (Illustrated.) By C. P. Steinmetz. THE COST OF ELECTRICITY IN SOME TYPICAL BUILDINGS IN NEW YORK CITY. (Illustrated.) By P. R. Moses. Nos. 6 and 7, June and July, 1899. THE DETERMINATION OF THE WAVE FORM OF ALTERNATING CURRENTS WITHOUT A CONTACT MAKER. (Illustrated.) By Harris J. Ryan. ELEMENTS OF INTEREST TO SPEED REGULATION IN PLANTS DRIVEN BY WATER POWER. (Illustrated.) By Allan V. Garratt. THE PROTECTION OF SECONDARY CIRCUITS FROM FIRE RISKS. By Cary T. Hutchinson. PLEA FOR A WORKING STANDARD OF LIGHT. By S. Ervett Doane. MOTOR SPEED REGULATION. By Alton D. Adams. Nos. 8 and 9 August and September, 1899. ELECTRICITY IN COAL MINING. (Illustrated.) By J. P. Jackson and Frank P. Thompson. AIR GAP AND CORE DISTRIBUTED. (Illustrated.) By W. E. Goldsborough. TEST OF A 300-KILOWATT DIRECT CONNECTED RAILWAY UNIT AT DIFFERENT LOADS. (Illustrated.) By E. J. Willis. No. 10, October, 1899. OPERATING COSTS OF HORSE AND ELECTRIC DELIVERY WAGONS IN NEW YORK CITY. (Illustrated.) By Geo. F. Sever and R. A. Fliess. ELECTRIC AUTOMOBILES. (Illustrated.) By Elmer A. Sperry. SERIES ARC LIGHTING FROM CONSTANT CURRENT-TRANSFORMERS. (Illustrated.) By William Lispenard Robb. COST OF ARC LIGHTING. (Illustrated.) By H. H. Wait. AN AMERICAN PACIFIC CABLE. (Illustrated.) By George O. Squier. No. 11, November, 1899. THE POSSIBILITIES OF WIRELESS TELEGRAPHY. (A Topical Discussion.) New York and Chicago, Nov. 28, 1899. No. 12, December, 1899.

Contents of Vol. XVII, 1900.

NOTES ON ELECTRIC TRACTION UNDER STEAM RAILWAY CONDITIONS. By Edward C. Boynton. NOTES ON SINGLE-PHASE INDUCTION MOTORS. (Illustrated.) By Charles P. Steinmetz. A NEW METHOD OF TRACING ALTERNATING CURRENT CURVES. (Illustrated.) By Pitshugh Townsend. No. 1, January 1900. THE EVOLUTION OF SAFE AND ACCURATE FUSE PROTECTIVE DEVICES. (Illustrated.) By Joseph Sachs. No. 2, February, 1900. HYSTERESIS IN SHEET IRON AND STEEL. (Illustrated.) By Arthur Hillyer. No. 3, March, 1900. A PARADIMETER. (Illustrated.) By M. I. Pupin. EXPERT AND EXPERT EVIDENCE. By J. E. Hyde. A NEW TRANSMISSION DYNAMOMETER. (Illustrated.) By W. E. Goldsborough. A PERCENTAGE BRIDGE. (Illustrated.) By H. C. Parker. EDDY CURRENT LOSS IN TRANSFORMERS. By Pitshugh Townsend. WAVE TRANSMISSION OVER NON-UNIFORM CABLES AND LONG DISTANCE AIR-LINES. (Illustrated.) By M. I. Pupin. No. 4, April, 1900. CONDITIONS OF ELECTROLYTIC CORROSION IN BROOKLYN. By Samuel Sheldon. A PRACTICAL TRANSMITTER, USING THE SINE WAVE FOR CABLE TELEGRAPHY. (Illustrated.) By A. C. Crehore and G. O. Squier. No. 5, May, 1900. THE USE OF ALUMINIUM LINE WIRE, AND SOME CONSTANTS FOR TRANSMISSION LINES. (Illustrated.) By F. A. C. Perrine and F. G. Baum. Nos. 6 and 7, June and July, 1900. THE IMPERIAL PHYSICO-TECHNICAL INSTITUTION IN CHARLOTTENBURG. (Illustrated.) By Henry S. Carhart. Nos. 8 and 9, August and September, 1900. THE PARIS EXPOSITION OF 1900. Inaugural address by President Hering. No. 10, October, 1900. THE PLANT OF THE ST. CROIX POWER CO., OF WISCONSIN. (Illustrated.) By Henry Floy. THE MECHANICAL FORCES IN DYNAMOS CAUSED BY MAGNETIC ATTRACTION. (Illustrated.) By B. A. Behrend, No. 11, November, 1900 CATALOGUE OF MEMBERSHIP. No. 12, December, 1900.

Contents of Vol. XVIII, 1901, far as Published.

A NEW PAGE-PRINTING TELEGRAPH. (Illustrated.) By William B. Vacuzie. AIR-GAP AND CORE DISTRIBUTION. (Illustrated.) By W. Elwell Goldsborough, No. 1, JANUARY, 1901. IMPORTANT EUROPEAN ELECTRICAL AND ENGINEERING DEVELOPMENTS AT THE CLOSE OF THE NINETEENTH CENTURY. (Illustrated). By William J. Hammer, No. 2, February, 1901.